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Post-Infection changes in the sugar content of Papaya fruits incited by Anthracnose fungi*

By

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Anthracnose of papaya is a common disease. The authors, during their extensive survey of the papaya growing tracts and fruit markets located in different States of India, have observed that these anthracnose fungi cause considerable damage not only to the ripe fruits but also to young fruits at different stages of development. These fungi invading fruits grow at the expense of the nutrients present in the host tissue. Therefore, it is expected that these microorganisms would bring about drastic changes in various ingredients present in fruits.

The present investigation was undertaken to reveal changes in sugar content brought about by these pathogens in papaya fruits at three different stages of maturity. In order to attain this objective, infected fruit tissues were analysed at regular intervals with the help of paper chromatography and a quantitative estimation of the individual sugars were done.

Materials and Methods

The fruits of 'Coorg honey' variety of papaya (*Carica papaya* L.) were obtained from Allahabad Agricultural Institute, Naini. Fruits of the different stages of maturity, *viz.*, young, old unripe and old just-ripe, were inoculated with single-spore isolated of *Colletotrichum papayae* P. Henn. and *Gloeosporium papayae* P. Henn. and incubated at 25 ± 1°C. The experiment was commenced within 24 hours of collecting the fruit, and Granger and Horne's (1924) method was used for inoculation.

On every alternate day some fruits were taken out of the lot and tissue adjacent to the inoculated region was analysed for sugars. For this, 5 g of fruit tissue was removed and put into 15 ml of boiling 80% ethanol contained in a 25 ml beaker. After 5 minutes the content of the beaker was transferred to a ground glass homogenizer and made into a fine paste. This was again poured into a beaker and 20 ml of 70% ethanol was added. This was boiled on a water

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bath for 15 minutes, cooled, and the supernatant was filtered through Whatman No. 42 filter paper. Twenty ml. of 70% ethanol was added to the residue. Boiling and filtrations were done in the way mentioned above. This procedure was repeated thrice and finally the residuce was transferred to the filter paper and washed twice with 10 ml of hot 70% ethanol. The total filtrate collected was evaporated almost to dryness on a water bath and then the volume was raised to 10 ml by adding distilled water. This extract was further purified by centrifugation at 2000 r.p.m. for 30 minutes. Two dilutions of this extract were prepared in which the ratio of the extract and distilled water added were 1 : 1 and 1 : 3.

In each case 0·005 ml extract was analysed by circular paper chromatographic technique described by Ranjan *et al.* (1955). The developing solvents used were : (*i*) *n* – butanol – acetic acid – water (4 : 1 : 5 upper phase), (*ii*) *n* – butanol – pyridine – water (9 : 5 : 8), and (*iii*) *n* – butanol – ethanol – water (4 : 1 : 5, upper phase). Standards of known sugars were cochromatographed to facilitate identification. The spray reagent used was aniline – diphenylamine phosphate recommended by Buchan and Savage (1952) (5 vols. 4% aniline, 5 vols. 4% diphenylamine and 1 vol. phosphoric acid). After spraying with this reagent spots of sugars were revealed by heating the chromatograms at 110°C for 90 seconds.

A quantitative estimation of sugars was done with the help of photometric technique followed by Ghosh (1966). Maximum densities of sugar spots were measured directly on the chromatograms with a Photovolt photo-electric densitometer. A red filter was used and the readings were recorded at sensitivity 3. Spots developed from either the original extract or its dilutions were selected in such a way that the densitometer reading due to them ranged between 0·1 and 0·3. Since the sugars detected, *viz.*, glucose, fructose and sucrose, gave clear separation in *n*–butanol – acetic acid – water, spots developed in this solvent were taken for quantitative estimation. Standard calibration curves were prepared by plotting densitometer reading of sugar spots developed from 0·005 ml of known sugar solutions of different concentrations against the corresponding logarithmic values of these concentrations. From these curves the concentration of each sugar was calculated. Control fruits were also subjected to similar analysis. The result of each analysis was recorded on the basis of eight replicates.

Results

The results obtained have been shown in Figs. 1, 2 and 3.

It is evident from Fig. 1 that in young fruits comparatively small quantity of glucose and fructose was present. In control fruits slight increase in their concentrations was noticed as the incubation progressed, whereas in diseased fruit tissue there was rapid decrease. At the initial stage the rate of decrease in fructose content was comparatively less but at later stage this was more. In both *Collectotrichum* and *Gloeosporium* infected fruits there was rapid decline in glucose concentration. At the end of incubation period of 12 days no sugar could be detected in infected tissue.

It is clear from Fig. 2 that in healthy old but unripe fruits only glucose and fructose were initially present and the quantity of these sugars was slightly more than that present in young fruits There was a marked increase in the concentration of these two sugars at later stages of incubation. A small quantity of sucrose also made its appearance after 8 days of incubation. On the contrary, in diseased fruit tissue there was a rapid decrease in sugar content and no sugar could be

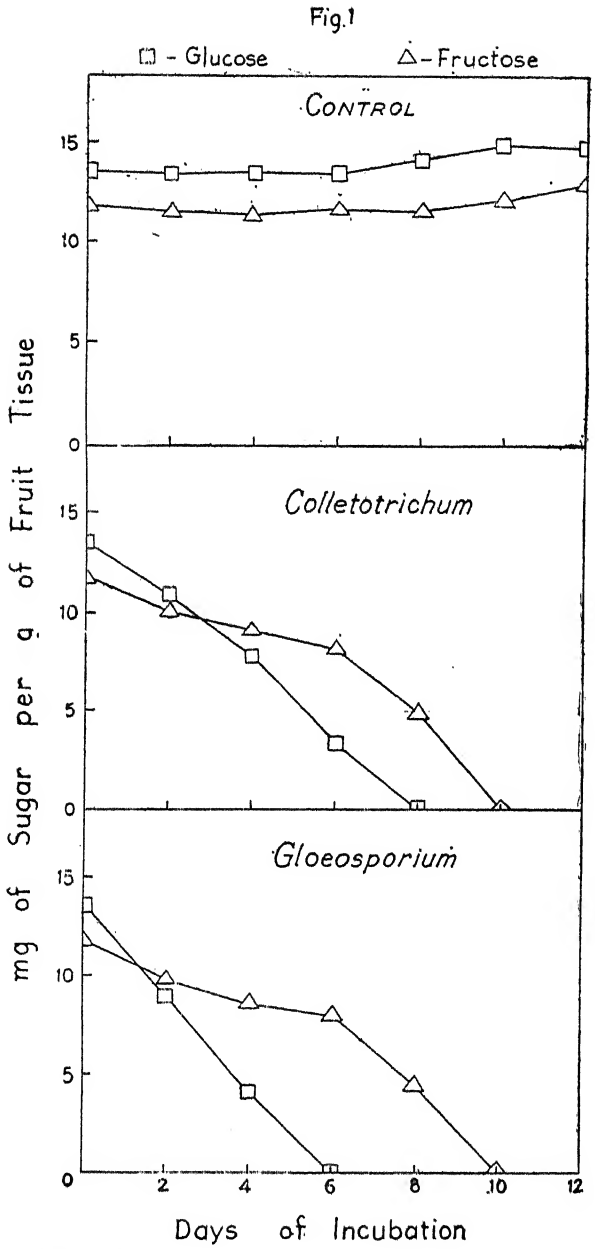
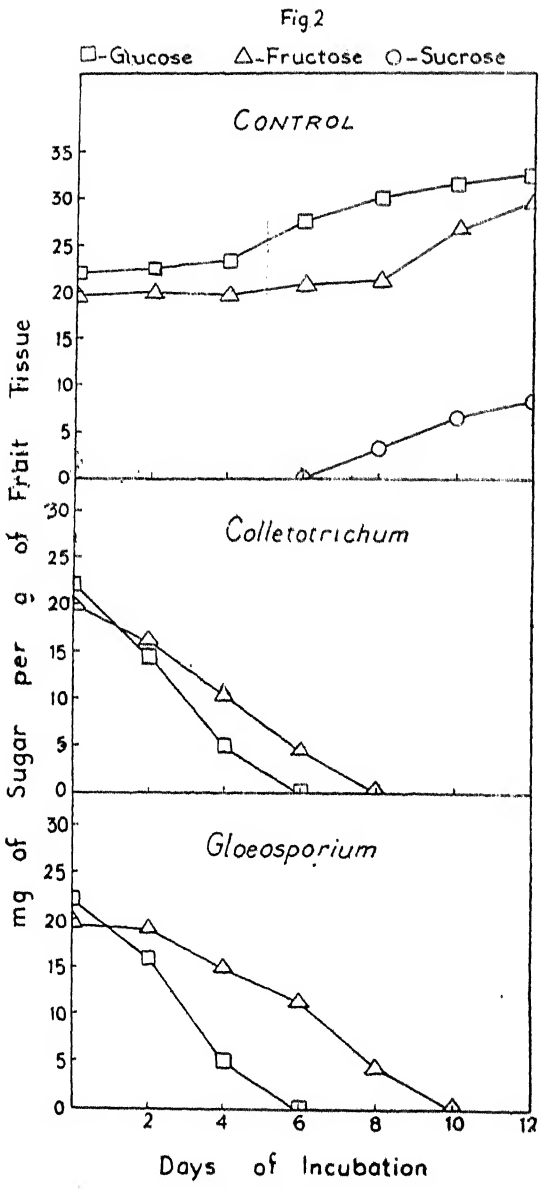


Fig. 1. Post-infection changes in the quantities of sugurs in young fruits of papaya.



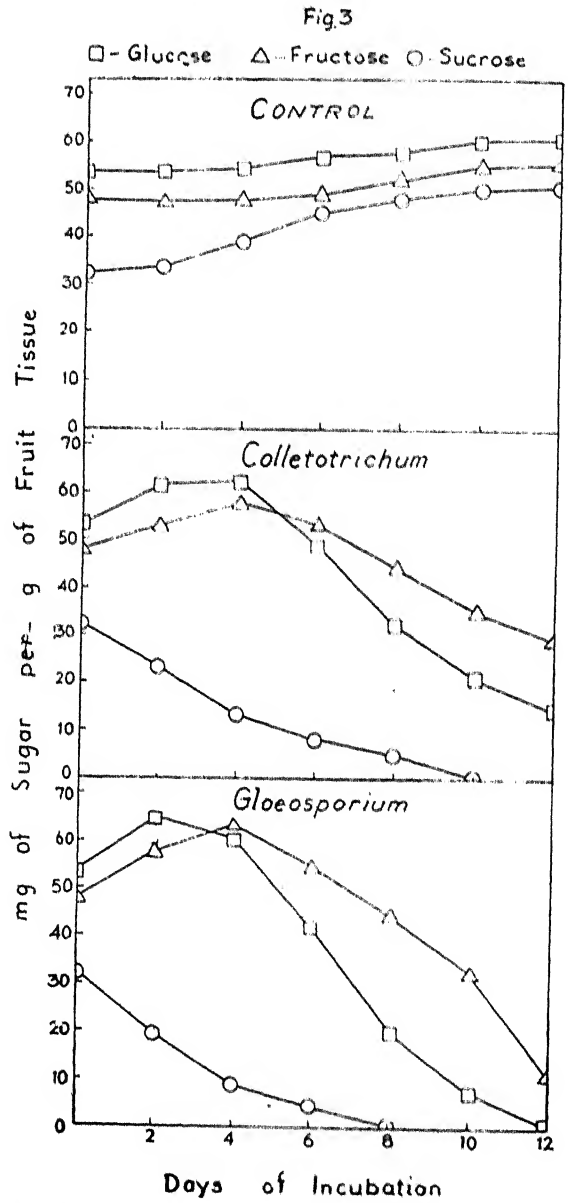


Fig. 2. Post-infection changes in the quantities of sugars in old unripe fruits of papaya.

Fig. 3. Post infection changes in the quantities of sugars in ripe fruits of papaya.

detected after 10 days of incubation. The rate of decline in fructose content was slightly slower in fruit tissue invaded by *Gloeosporium* as compared to that infected with *Colletotrichum*. No sucrose could be traced in infected fruits at any stage.

Fig. 3 shows that in just-ripe fruits of papaya sucrose was also present in addition to glucose and fructose. The quantity of sucrose was initially much less as compared to that of glucose or fructose. In healthy fruits there was a marked increase in sucrose concentration towards the end of the incubation period, whereas increase in the quantities of glucose and fructose was slight. In infected fruit tissue there was a rapid decrease in sucrose content from the early stages of incubation and this sugar could be detected upto 6 and 8 days respectively in the fruit tissues infected by *Gloeosporium* and *Colletotrichum*. On the other hand, both glucose and fructose concentration showed an increase in the early stages of incubation, although at later stages there was rapid decrease. This decline was comparatively more pronounced in *Gloeosporium* infected fruit tissue and in this case no glucose could be detected at the end of the incubation period of 12 days.

Discussions and Conclusions

It is evident from the results obtained that quantities of sugars showed a gradual decrease in infected fruits. On the other hand, in healthy fruits there was an increase in sugar content which was more pronounced in old unripe and ripe fruits of papaya. Appearance of sucrose in old unripe fruits on prolonged storage could be ascribed to ripening.

In infected fruit tissue of ripe papaya the initial increase in glucose and fructose concentrations apparently denoted hydrolysis of sucrose. This was evidenced by the fact that there was a corresponding decrease in sucrose content at this stage. Earlier, Ghosh *et al.* (1964) had observed similar phenomenon in infected fruit tissues of some tropical fruits. In the present study it was observed that at later stages of infection the decrease in quantity of glucose was more as compared to that of fructose. This appears to be due to a preferential utilization of glucose by these microorganisms.

The post-infection change in sugar content of papaya fruits brought about by *Colletotrichum papayae* was, in general, similar to that incited by *Gloeosporium papayae*. Minor differences, however, were observed. For instance, in young fruits glucose disappeared earlier in *Gloeosporium* infected tissue as compared to that invaded by *Colletotrichum*.

The rapid decrease in the quantity of sugars in diseased fruits was obviously due to fungal activity. Since sugars play an important role in the nutrition of these fungi, it is natural that the free sugars present in the infected fruit tissue would be metabolized readily. Moreover, fungal infection would enhance the rate of respiration of the host causing an additional decrease in sugar content.

Summary

Papaya fruits of three stages of maturity, *viz.*, young, old unripe and ripe, were inoculated with *Collectotrichum papayae* and *Gloeosporium papayae*. Fruit tissue adjacent to the inoculated region was analysed for sugars with the help of paper chromatography and a photometric estimation of individual sugars was done at regular intervals.

Glucose and fructose were present in healthy young and old unripe fruits which showed an increase in their concentrations during storage. There was rapid decrease in sugar content of infected fruit tissue and no sugar could be detected

at the end of incubation period of 12 days. In healthy ripe fruits sucrose was also present in addition to glucose and fructose and in storage there was a marked increase in sucrose concentration. At initial stage the infected tissue of ripe fruits showed a rapid decrease in sucrose content and a simultaneous increase in the quantity of glucose and fructose ; but at later stages there was a rapid decrease in glucose and fructose content.

Acknowledgements

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The Head-skeleton of Fishes of the Order Beloniformes
I. *Xenentodon cancila* (Ham.)*

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Introduction

The references are available only from Regan (1911), who described the osteological features of Synentognathi (Scombresocidae of Gunther, 1866 and Beloniformes of Berg, 1940), Lasdin (1913) on the skull of *Exocoetus*, Durga Das (1957) of *Belone cancila* and Mathur *et al.*, (1960) that of *Hemirhamphus xanthopterus*. Starks (1926) studied the ethmoidal region of certain members of Belonidae, Hemirhamphidae and Exocoetidae. Moreover the placement of fishes of this order has remained controversial and needs confirmation on osteological features. With this in view the study of head-skeleton of fishes of the order Beloniformes has been undertaken. De Beer's (1937) terminology has been followed, except for the lower jaw bones, for which the nomenclature from Haines (1937) has been adopted.

Material and Methods

The fish (*Xenentodon cancila*) is commonly available in Indian waters. It feeds voraciously, swimming near the surface. The larvae pass through the hemirhamphus phase before developing into an adult. It attains a maximum length of about a foot. Red alizarin transparencies were prepared from locally collected specimens. Adding a few ml. of hydrogen peroxide for a day to the clearing jar improved clearing of the specimens. The hydrogen peroxide had to be washed off thoroughly so that the bones might take a proper stain. The transluscent specimens were kept in acetone for about two days to dissolve out the fat, which would otherwise stain deeply.

The Skull

The *skull* is superficial, uninterrupted and tropibasic. It is elongated and bears a pair of diverg nt horns behind. The orbitosphenoid, pleurosphenoids, parietals, epistlotics, supratemporals, entopterygoids and interhyals are absent.

The Cranium

The *cranium* is flat and depressed in front. The posterior myodome is wanting, internasal septum of thick cartilage and the interorbital septum membranous. The orbits are placed much ahead of the auditory region.

*Part of the Ph.D. thesis of Agra University, Agra.

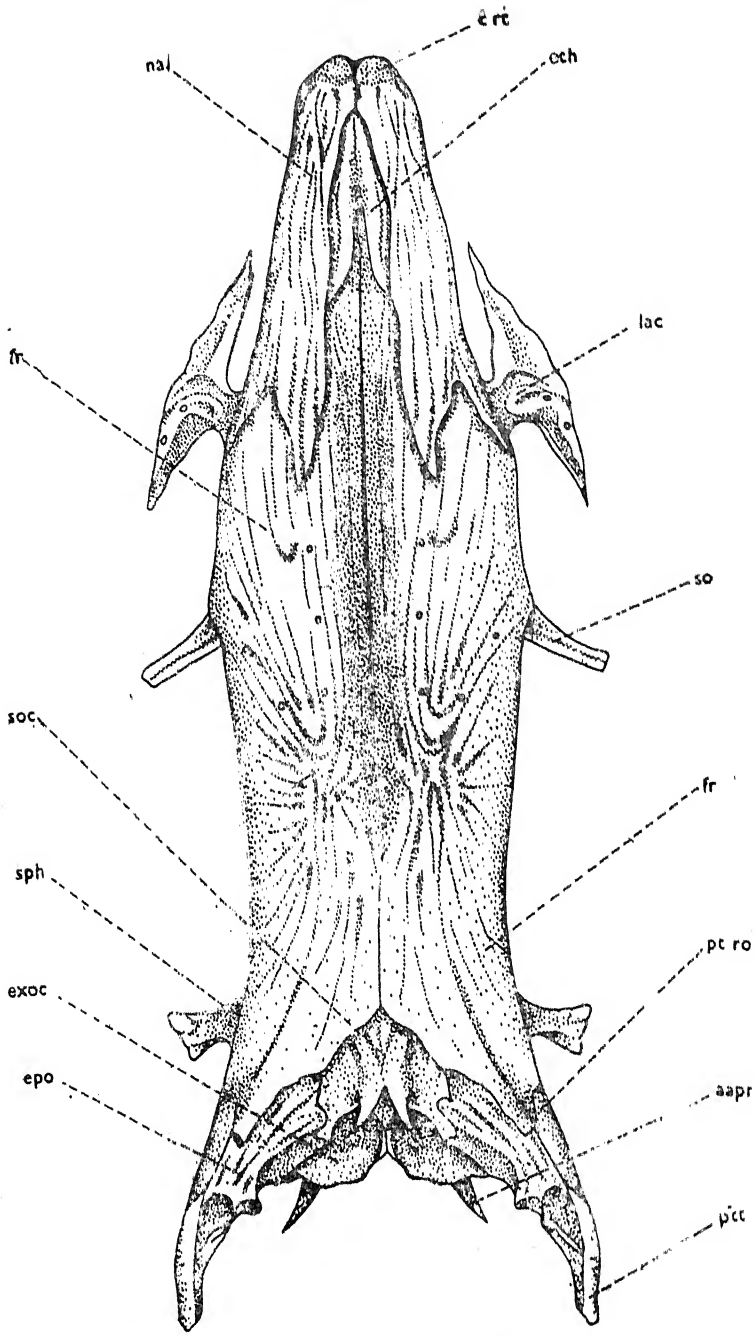

PLATE 1. Dorsal view of cranium.

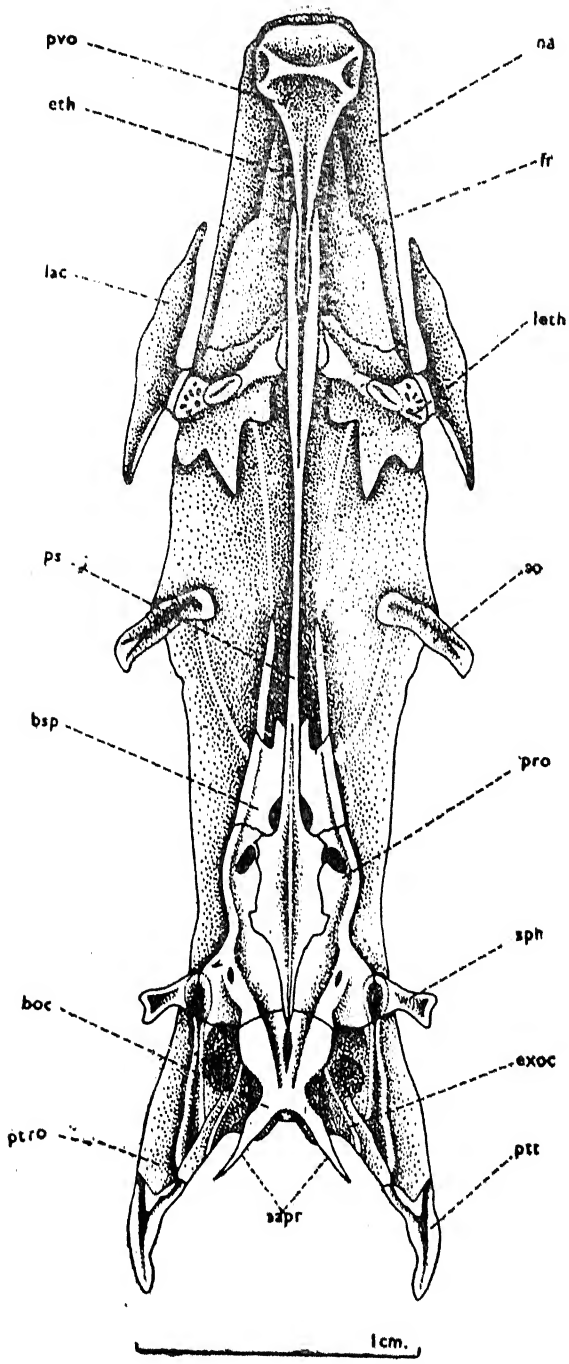

PLATE 2. Ventral view of cranium.

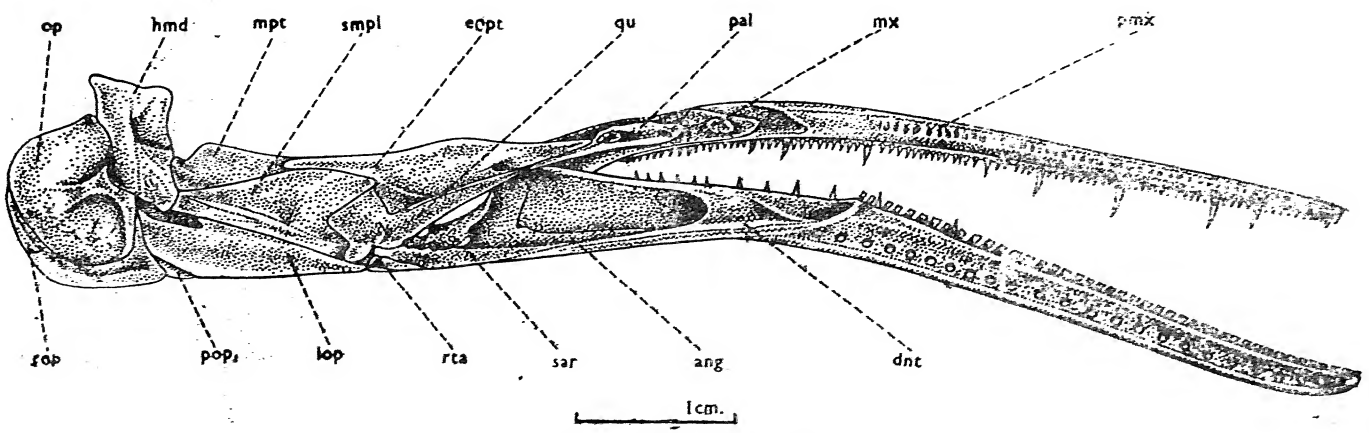

PLATE 3. Inner view of mandibular and hyoid arches.

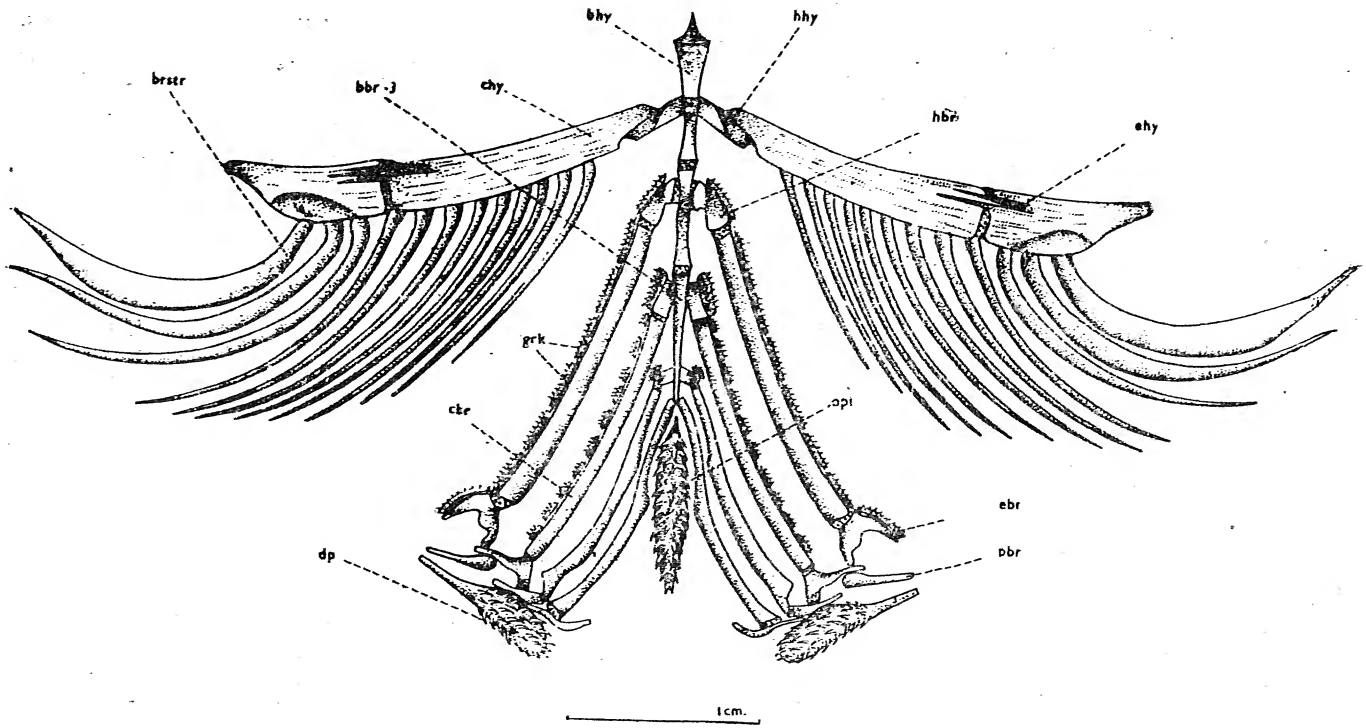

PLATE 4. Hyoidand branchial arches.

ABBREVIATIONS USED

aapr., accessory articular process; ang., angular; bbr-3,, third basibranchial; bhy., basihyal; boc., basioccipital; brstr., branchiostegal ray; bsp., basisphenoid; cbr., ceratobranch; chy., ceratohyal; crt., cartilage; dnt., dentary; dp., dentigerous pad; ebr., epibranch; ecpt. ectopterygoid; ehy., epihyal; epo., epiotic; eth., ethmoid; exoc., exoccipital; fr., frontal; grk., gill rakers; hbr., hypobranch; hhy., hypohyal; hmd., hyomandibula; iop., interopercle; lac., lachrymal; leth., lateral ethmoid; mpt., metapterygoid; mx., maxilla; na., nasal; op. opercle; opi., os pharangeum inferius; pal, palatine; pbr., pharyngobranch; pmx., premaxilla; pop., preopercle; pro., prootic; ps., parasphenoid; ptro., pterotic; ptt., postemporal; pvo., prevomer; qu., quadrate; rta., retro-articular; sar., sesamoid; smpl., symplectic; so., suborbital; soc., supraoccipital; sop., subopercle; sph., sphenotic.

The *ethmoid* is elongated, being concave below and deeply notched behind. It is surrounded by the nasals and frontals. The *lateral ethmoid* is small, slightly curved and irregular lying away from the ethmoid. It contributes to the olfactory recess and anterior boundary of orbit. The bone has a notch for the olfactory tract and articulates with the lachrymal, nasal, frontal, and ectopterygoid. The *nasal* is flat and elongated overlapping the ethmoid and frontal. The two nasals form a median dentate suture anteriorly. Each bone is traversed by the supra-orbital lateral line canal. It articulates with the lateral ethmoid, prevomer and maxilla. The *prevomer* is elongated, edentulous and arrow-shaped. It is comprised of a broad body and a narrow stem. The body bears a dumb-bell-shaped transverse ridge below. The bone articulates with the nasals, parasphenoid and palatines.

The *frontal* is long, flat and with feeble ridges radiating from a common centre. It is narrow at both the ends and in the posterior half it has a small inferior ridge, which interdigitates with the basisphenoid and prootic. It is traversed by the supraorbital and temporal lateral line canals and articulates with the pterotic and epiotic. It overlaps the lateral ethmoid, suborbital, sphenotic and supraoccipital and its tip underlies the nasal. The *basisphenoid* is a Y-shaped bone. Its inferior limb has a groove for the parasphenoid and the two dorso-lateral limbs interdigitate with the frontal, prootic and parasphenoid. The *parasphenoid* is elongated comprising the small plate-like body and narrow elongated stem. The body contributes to the cranial floor and is produced into a small process behind. The stem is laterally compressed in the posterior half and flat in the anterior half. The anterior end is upturned and bifid for the prevomer. The bone interdigitates with the basisphenoid and articulates with the prootics and basioccipital. It is attached by ligaments to the palatines and ectopterygoids.

The *lachrymal* is a triangular bone overlapping the premaxilla and maxilla with its lower end lying free in the tissues. It forms the lower boundary of olfactory recess and anterior boundary of oribit. The bone articulates with the lateral ethmoid. The *suborbital* is a small splint-like bone, which hangs from the outer margin of frontal forming the posterior limit of orbit. The lachrymal and sub-orbital are traversed by the infraorbital lateral line canal.

The *sphenotic* is irregular and is distinguished into the body and process. The bone articulates with the pterotic, prootic and hyomandibula and is overlapped by the frontal. The *pterotic* is an elongated and laterally compressed bone. It lodges a part of the posterior vertical semicircular canal of internal ear. The bone articulates with the frontal, sphenotic, prootic, epiotic, exoccipital, posttemporal and hyomandibula. The *prootic* is irregular and forms the floor and side wall of the auditory region. It gives off a horizontal plate in its posterior half, which meets its counterpart. The anterior halves of the two prootics enclose a gap, which is covered by the parasphenoid. Each bone has a trigeminofacial camplex fenestra and an aperture for the hyomandibular trunk of facial nerve. The bone interdigitates with the frontal and basisphenoid and suturally articulates with the parasphenoid, sphenotic and basioccipital. The *epiotic* is elongated and articulates with the frontal, pterotic, exoccipital and posttemporal. It overlaps the supra-occipital.

The *supraoccipital* is flat and distinguished into the anterior horizontal part and posterior depressed part. The anterior part is circular and is produced into a long median process in front. It also gives out a pair of lateral horns and a deeply forked occipital process. The depressed part is triangular and lies between the exoccipitals. The bone is overlapped by the frontals and epiotics. The

exoccipital is an irregular bone distinguished into the body, neural plate and horizontal plate. The body has an aperture for the glossopharyngeal and vagus nerves. The neural plates of the two sides curve upwards and inwards binding the foramen magnum. The horizontal plate is feeble and arises at the junction of body and neural plate. It is directed inwards and rests over the basioccipital. The bone articulates with the pterotic, prootic, supraoccipital, basioccipital and posttemporal and bears an accessory articular facet for the first vertebra. The *basioccipital* is a somewhat triangular bone. Its cranial surface has a median longitudinal groove and a shallow concavity on either side of the groove. It gives out a pair of large backwardly and outwardly directed accessory articular processes, which lie below the transverse processes of the second vertebra. The bone articulates with the parasphenoid, prootics, exoccipitals and first vertebra.

The *posttemporal* is distinguished into the body and laterally compressed superior and inferior limbs. The body articulates with the supracleithrum, the superior limb with the pterotic and epiotic, while the inferior limb with the exoccipital.

The Mandibular Arch

The jaws are produced into a long beak and the gape is exceptionally wide. The palate is edentulous. The *premaxilla* is elongated forming almost the entire upper beak. It is beset with an inner row of large and an outer row of much smaller teeth. The bone articulates with the nasal, underlies the lachrymal and overlaps the maxilla. The *maxilla* is a small slightly curved and twisted bone. It is laterally compressed and lies at the angle of mouth firmly attached to the inner surface of premaxilla. Its inner surface has two depressions, one for the nasal and another for palatine. It is attached by ligaments to the dentary. The *palatine* is small and dagger-shaped placed independent of ethmoid and lateral ethmoid. It is broad in front and narrow behind. The broad part lies between the prevomer and maxilla, while the narrow part is surrounded by the maxilla, ectopterygoid and quadrate. The bone is attached to the parasphenoid by ligaments. The *ectopterygoid* is small and dagger-shaped placed above the palatine and quadrate. The two ectopterygoids form a keel below the parasphenoid. Each bone articulates with the lateral ethmoid and symplectic. It is attached to the parasphenoid ligamentously and is overlapped by the metapterygoid. The *metapterygoid* is small plate-like being broad in front and narrow behind. Along the outer surface of bone is an oblique ridge, which is continuous with that of symplectic. The two metapterygoids form a keel, which is continuous with that of ectopterygoids. The bone underlies the hyomandibula and symplectic and overlaps the ectopterygoid. The *quadrate* is elongated and distinguished into the plate-like body and long process. The body bears a condyle for the angular and gives off behind a projection with a narrow elongated groove for the interopercle and preopercle. The process is tapering, upwardly directed and lies inserted between the palatine and ectopterygoid. The bone also articulates with the sesamoid articular and overlaps the symplectic. The *retroarticular* is small and triangular being broad behind and tapering in front. It is hidden by angular and is connected with the interopercle. The *angular* is a dagger-shaped bone, broad behind and tapering in front. It has a concavity for the quadrate behind and a small forwardly and upwardly directed process. The bone is inserted into the dentary and articulates with the sesamoid articular and retroarticular. The *sesamoid articular* is an irregular bone attached to the inner surface of angular and is almost invisible externally. It has a facet along the inner surface for quadrate. The *dentary* is elongated forming the entire lower beak and bearing teeth like those of premaxilla. The two dentaries interlock through a series of projections

forming the mandibular symphysis. The symphysis has a broad median ridge above and a deep longitudinal groove below. The bone articulates with the angular and is connected with the maxilla by ligaments. The angular and dentary are traversed by the mandibular segment of operculomandibular lateral line canal.

The Hyoid Arch

The *hyomandibula* is a stout and somewhat rectangular bone bearing two almost confluent condyles above. The anterior condyle articulates with the sphenotic and prootic and the posterior one with the pterotic. The hind edge also bears a condyle for the opercle and a groove for the preopercle. The lower edge abuts against the symplectic and articulates with the epihyal. The hyomandibular trunk of facial nerve enters the bone on the inner aspect and emerges on the outer one. The bone overlaps the metapterygoid. The *symplectic* is elongated and roughly triangular with the anterior end broad and notched. It is overlapped by the metapterygoid, quadrate and preopercle. The *epihyal* is a small flat bone. Its distal end articulates with the hyomandibula and symplectic. The bone bears three branchiostegal rays. The *ceratohyal* is flat and elongated with a broad distal and a narrow proximal end. The distal end partly interdigitates with the epihyal and the proximal end articulates with the hypohyal. It bears nine branchiostegal rays. The *hypohyal* is a small, slightly twisted and rod-like bone, which articulates with its counterpart, ceratohyal, basihyal, urohyal and first basibranch. The *basihyal* is a flat, conical and edentulous bone with its broad front end produced into a sharp spine. It articulates with the hypohyals and first basibranch. The *urohyal* is a greatly elongated and laterally compressed bone, which is bifid in front and deeply forked behind. The two limbs of the fork are unequal and bifid.

The *opercle* is a flat semicircular bone extending behind beyond the occiput. It has a concavity for the hyomandibula and abuts against the subopercle and preopercle. The *subopercle* is the smallest of the series and is elongated and curved. The *interopercle* is an elongated flat bone lying almost completely hidden by the preopercle. It articulates with the quadrate and remains connected with the retroarticular and subopercle. The *preopercle* is a L-shaped bone distinguished into the large and broad horizontal limb and small and slender vertical limb. The horizontal limb overlaps the interopercle, while the vertical limb lies in the groove of hyomandibula. The bone articulates with the quadrate and hyomandibula and overlaps the symplectic. The bone is traversed by the opercular segment of the operculomandibular lateral line canal.

The Branchial Arches

The *pharyngobranchs* are two club-shaped structures on either side, one being small and edentulous and the other large and dentigerous. The first *epibranch* is flat and V-shaped bearing minute gill rakers. Its outer limb lies free and the inner limb articulates with the second epibranch. The rest of the epibranchs are elongated and slightly curved bones. Each epibranch articulates with the corresponding ceratobranch. The *ceratobranchs* are developed on all the arches. The first two bear minute gill rakers and the fifth forms with its counterpart, the *os pharyngeum inferius*, which is beset with numerous infrapharyngeal teeth above. The *hypobranchs* are small bony pieces developed on the first three arches and bear minute gill rakers. The first two hypobranchs are aligned with the corresponding ceratobranchs, while the third is transversely placed and articulates with the third basibranch. The *basibranchs* are three rod-shaped bones forming a copula.

Discussion

The maintenance of the old nomenclature *Belone cancila* by Durga Das (1957), despite its placement under *Xenentodon cancila* by Shaw and Shebbeare (1937), Fowler (1938), Hora and Law (1941), Smith (1945), Deraniyagala (1952) and Chauhan and Ramakrishna (1953), might be an oversight.

The ethmoid is a median bone in *Tylosurus* (Starks, 1926), *Hemirhamphus xanthopterus* (Mathur *et al.*, 1960) and *Xenentodon*, but Durga Das (1957) describes it as a large median cartilage in *B. cancila*. Starks (1926) records that the prevomer bears teeth and projects slightly beyond the ethmoid in *Criodorus* and considerably in *Parexocoetus*, but in *H. xanthopterus* (Mathur *et al.*, 1960) and *Xenentodon* it does not project beyond the ethmoid and is edentulous. The frontals were considered to be cartilaginous in *H. xanthopterus* (Mathur *et al.*, 1960), but they are distinct bones in *Xenentodon*. The parietals were found to be articulated medially in *Belone* (Durga Das, 1957), but Regan (1911) remarks that the parietals are absent in synentognaths and if present they are separated by the supraoccipital. In *Xenentodon*, however, parietals are found to be absent. Lasdin (1913) considers the pleurosphenoids to have been fused with the frontals in *Exocoetus*, Durga Das (1957) and Mathur *et al.*, (1960) record the presence of these bones in *Belone* and *Hemirhamphus* respectively, but they could not be separated in *Xenentodon*. Durga Das (1957) considers the incomplete orbital ring as a characteristic feature of the genus *Belone*, but this feature is quite common among synentognaths. She considers the orbitosphenoids and supraorbitals as paired bones in *Belone*, but these bones are not found to have been ossified in *Xenentodon*. The absence of these bones has already been noted by Regan (1911) in synentognaths. The basisphenoids are paired in *Hemirhamphus* (Mathur *et al.*, 1960), but only a median basisphenoid has been observed in *Xenentodon*. Durga Das (1957) observed small opisthotics in *Belone*, which is against the observations of Regan (1911) in *Belone*, Mathur *et al.*, (1960) in *Hemirhamphus* and that of the author in *Xenentodon*. The retroarticular and sesamoid articular have not been described by Durga Das (1957) in *Belone* and by Mathur *et al.*, (1960) in *Hemirhamphus*, but Regan (1911) considered them to be present in synentognaths and these bones have also been noted by the author in *Xenentodon*. Durga Das (1957) records the presence of endopterygoids (entopterygoids) and interhyals in *Belone*, which could not be confirmed in *Xenentodon*. Durga Das (1957) noted 11 branchiostegal rays in *Belone cancila*, but 12 such rays are noted in the present study. Durga Das (1957) records a single pair of toothed pharyngobranchs in *Belone*, but a toothed and an edentulous pair are noted in *Xenentodon*. Regan (1911) mentioned three pairs of toothed pharyngobranchs in *Belone*, *Scombresox* and *Tylosurus*, but a single pair in *Xenentodon*. Durga Das (1957) observes superior pharyngeal teeth on the dorsal surface of the pharyngobranchs, which might be an oversight, because as a rule they are borne on the ventral surface. The gill-rakers are considered vestigeal by Regan (1911) in synentognaths, absent by Deraniyagala (1952) in *Xenentodon*, but were found to be present as minute structures in the present study. Durga Das (1957) describes a hyostylic suspensorium in *Belone*, but according to de Beer (1937) it is methyostylic in teleosts.

Summary

The skull is superficial, uninterrupted and tropibasic. It is elongated and the jaws are produced into a long beak. The orbitosphenoid, pleurosphenoids, parietals, opisthotics, supratemporals, entopterygoids and interhyals are absent.

The lateral ethmoid is placed independent of ethomid. The nasals articulate medially and overlap the ethomid. The prevomer is edentulous. The inferior

limb of basisphenoid is grooved and the parasphenoid contributes to the cranial floor. The posterior myodome is wanting. The circumorbital series is represented by the triangular lachrymal and solitary suborbital. The bones of the auditory region do not contribute to orbit boundary. The exoccipital has an accessory articular facet and the basioccipital bears diverging accessory articular processes. The palate is edentulous and the ectopterygoids and metapterygoids form a continuous keel. The premaxilla is toothed and is much longer than the maxilla. The dentaries form a symphysis by an interlocking arrangement. The epihyals suspend the hyoid cornua from the hyomandibulae and symplectics directly. The branchiostegal rays are 12. The urohyal is deeply forked behind, each of the two limbs of the fork being bifid again. There are two pairs of pharyngobranchs. The suprapharyngeal teeth are borne on the second pair of pharyngobranchs and the infrapharyngeal ones on the *os pharyngeum inferius*. The gill rakers are borne on the first epibranch, first and second ceratobranchs and on all hypobranchs.

Acknowledgements

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An analysis of the Catch Statistics of the Commercial Fishery of the Gangetic Anchovy, *Setipinna phasa* (Hamilton)

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Introduction

The judicious management of a fishery concerns itself with so regulating it that maximum possible return from the resource is obtaind without depleting the supply. In other words, it seeks to maintain a balance between the fish stocks and the intensity of fishing mainly in the form of an optimum catch. Apart from the biological factors, the total amount of any species taken at a time is dependent on several other factors, *viz.*, fishing effort, shift in fishing grounds, weather, changes in other fisheries, labour and economic conditions (Graig, 1930).

Market measurements and estimation of fish landings at selected riparian centres along the rivers Ganga and Yamuna gave considerable information on samples of *Setipinna phasa* (Ham.) landed in commercial operations. The present paper attempts to elucidate the significant features of the Gangetic anchovy fishery by analysing the gross data collected on the type of fishing operations or gear and the distribution of catches relative to season, year and locality.

Material and methods

The catches of *S. phasa* were estimated at the following riparian centres along the rivers Ganga and Yamuna during the years 1958 to 1962 :

River Ganga

1. Kanpur
2. Daraganj (Allahabad)
3. Varanasi
4. Ballia
5. Buxar
6. Patna
7. Bhagalpur

River Yamuna

1. Agra
2. Sadiapur (Allahabad)

After authentic ageing, the fish were classified into various age-groups. The number of *S. phasa* falling within various age-groups, according to their lengths, was counted separately. The average length of each age-group of this species was determined at the spot and weights of average length were computed from the length-weight relationship equation determined for this species. The weights, thus determined, were multiplied with the number of fishes counted to get the total weight of fish in each age-group.

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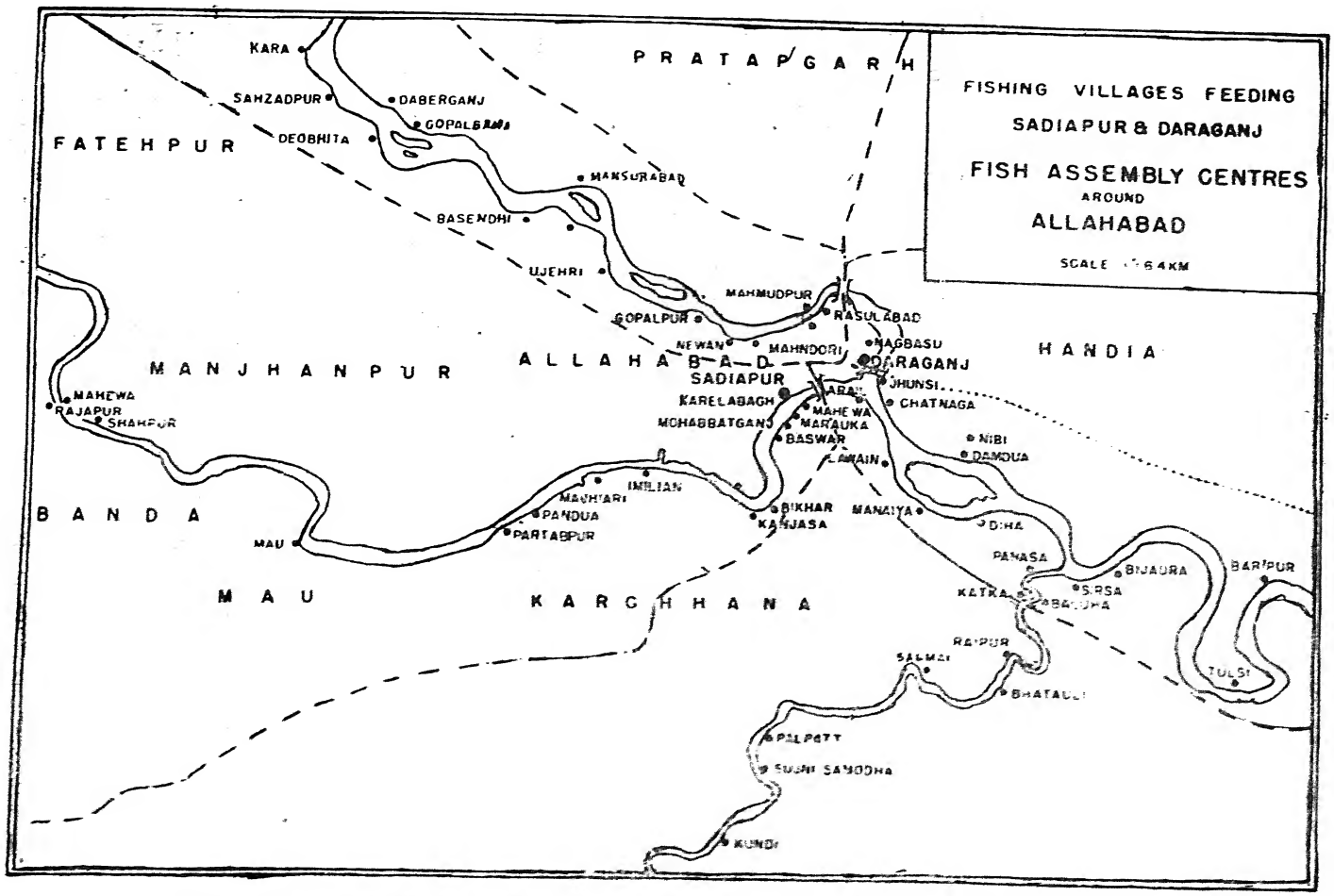

Fig. 1. Map of the Ganga river system showing area of investigation in and around Allahabad.

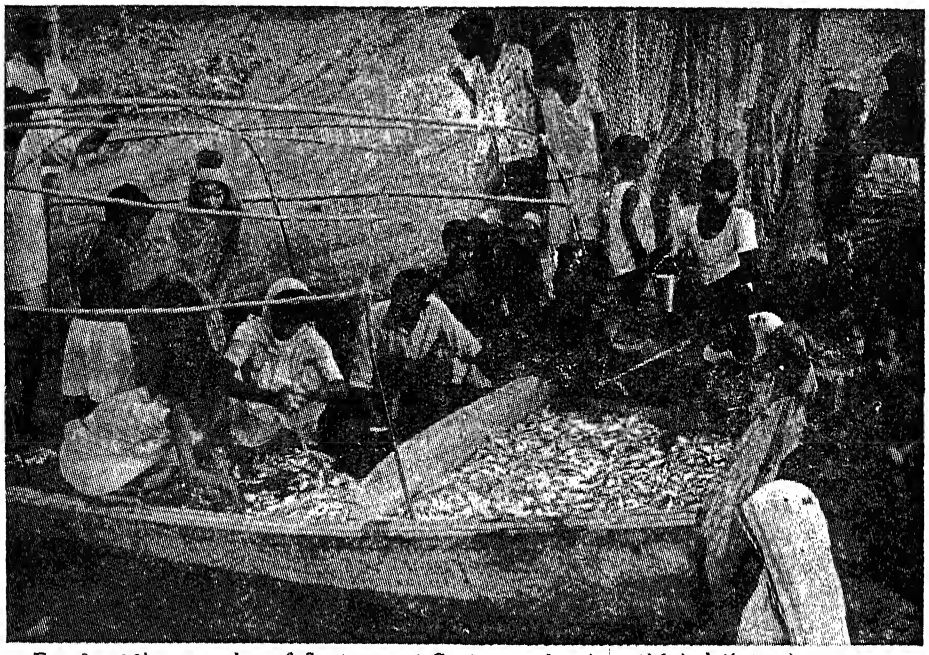

Fig. 2. Mixed catches of *S. phasa* and *G. chapra* taken by a 'Mahajal', the latter seen in the background.

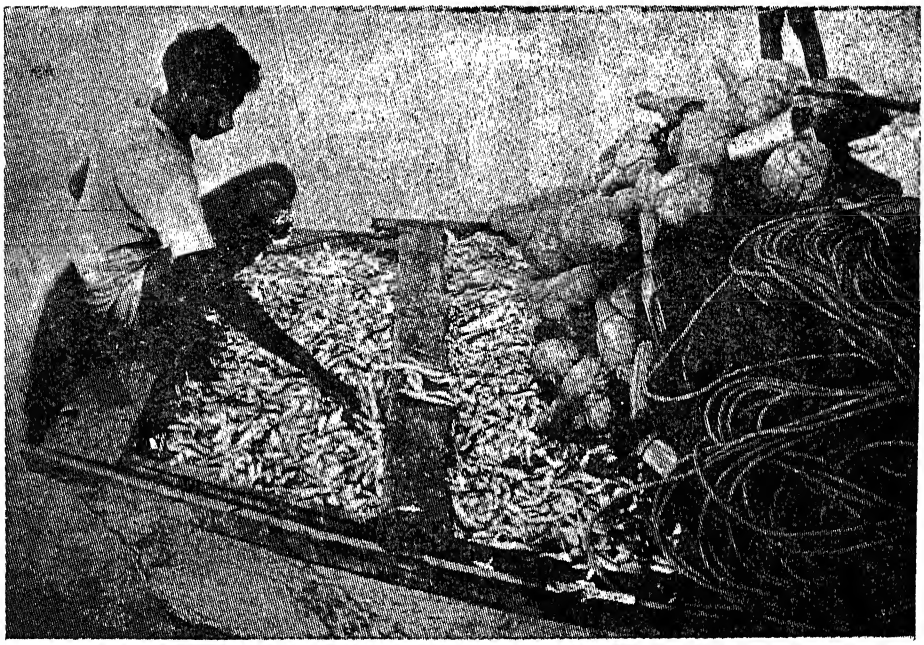

Fig. 3. Mixed catches of *S. phasa* and *G. chapra*, taken from river Yamuna by a 'Mahajal'. The floats and the mesh-size of this dragnet are also seen.

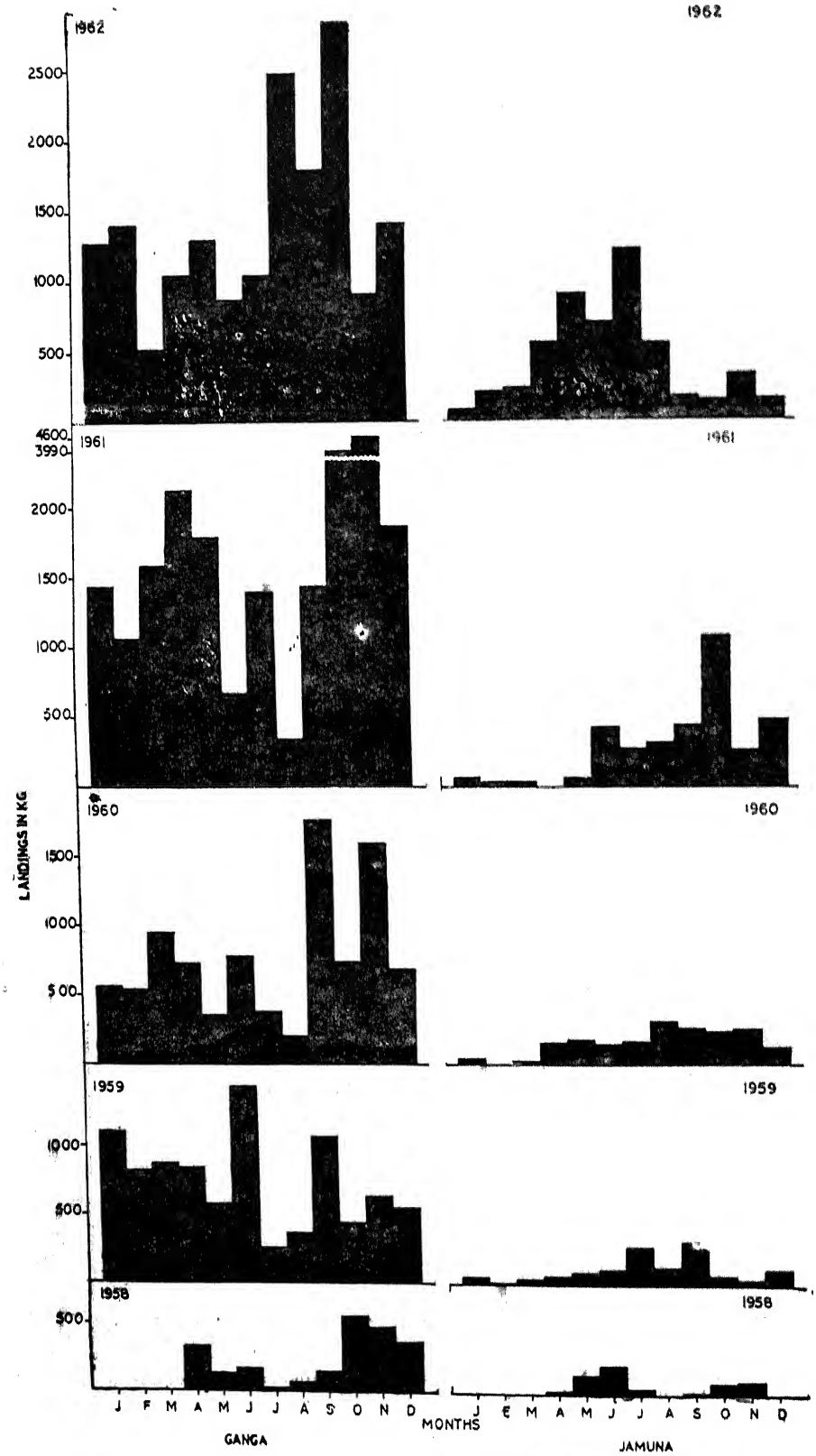

Fig. 4. Monthly landings of *S. phasa* from rivers Ganga and Yamuna.

The entire data pertaining to various aspects of fishing activity were recorded in field during visits to fishing sites and villages (Fig. 1). All measurements were taken while the fish were in fresh condition. The lengths of the fish were measured on an ordinary fish-measuring board marked in millimetres and the total weights taken on a sensitive platform balance, the accuracy being 0·1 g.

Fishing gear

A wide variety of nets are used for catching *S. phasa*. However, no single net has so far been designed to capture *S. phasa* exclusively and the species is caught along with other fishes in nets varying in size, mesh and number of pieces differing from place to place. The choice of net depends on current velocity, river depth and other hydrological features of the river. According to Saxena (1965) Ganga above its confluence with Yamuna is a fast flowing river, the gradient of the river is steep and current remains fast throughout the year even during monsoon when the river swells up considerably. River Yamuna, on the other hand, is sluggish with deep pools and steep banks, the latter preventing the horizontal spreading of the water area during monsoon months. Above the confluence, the Ganga is turbid all the year round wheras the Yamuna, except during monsoon months, has clear water. These differences in the hydrological and topographical features of the two rivers are mainly responsible for development of different fishing gear during different seasons and stretches of both the rivers. A brief description of the nets which catch *S. phasa* together with other fishes is given below :

A. Drag net

1. *Mahajal* : This net (Figs. 2 and 3) is more prevalent and used all through the year except during monsoons. The total number of pieces that join to form a composite *Mahajal* varies from place to place depending on the water level, available man-power and financial resources. This rectangular net is composed of about 50–55 pieces and has a length and depth of 7 and 3 m respectively. The size of the mesh, when stretched, ranges between 5·8 to 6·5 cm. 8–25 fishermen are required to operate the net with the help of a large-sized boat. 6–10 fishermen hold the net on the bank while a contingent of 6–10 pays out the net in a semi-circular fashion. The whole party drags out the net to the bank when the catch has accumulated in the central piece. The net is provided with floats at the upper margin and earthen or iron weights are hung to the lower margin. The peak months of its operation are from December to February.

2. *Darwari* : A large percentage of *S. phasa* catch, landed at Sadiapur fish assembly centre, is contributed by this net alone. This is also a dragnet, like *Mahajal*, similar in shape and *modus operandi*, the only difference being in the mesh-size (2·4–3·8 cm.). The sinkers used with this net are smaller as compared to those used for *Mahajal*. Though operated throughout the year, this net stands as the main net of the commercial fishery during monsoon months when the fishermen refrain from operating other nets in the main stream due to greatly enhanced depth and fast current of the flooded river. A number of places are attached breadthwise and the net dragged in enclosed, relatively shallow, areas of the rivers, 15–25 men and a big boat are needed during operation.

3. *Pandi* : The dimensions of this net are similar to those of *Darwari* excepting that it has smaller mesh (0·65 to 1·27 cm). There is one row of pockets each capable of holding about one kilogram of fish. It is generally used in feeble currents in summar, capturing mostly *Gudusia chapra, Clupisoma garua, Eutropiichthys*

vacha, Chela sp. and *Labeo bata* besides *S. phasa*. 2-4 men and a small boat are required to operate this net. The net is made of fine cotton yarn.

4. *Do-dandi or Ghogoa* : The net is in the form of a pouch and this simple dragnet is composed of one or two pieces only, each 9·6 m long and 4·35 m in depth with six to eight floats to the head rope and 20 sinkers to the foot rope. Mainly operated in shallow waters, when two men are required to drag the net to the bank with the help of two vertical poles attached to the either end. The season of its operation is from May to September. Besides *G. chapra* and *S. phasa*, mostly *Chela* sp., *Aspidoparia* sp., and clupeoids other than *Hilsa ilisha* are caught in this net.

B. Gill nets

1. *Ghank* : This net is 90–125 m long and 1·1 to 1·3 m deep, the mesh-size varying from 0·42 to 1·27 cm. Made of fine cotton yarn, this net has light floats and is used extensively in summer. Only one man can operate this net. *S. phasa, C. garua, E. vacha, G. chapra* and *Gonialosa manminna* are mostly captured.

C. Cast net

1. *Bhanwar jal* : This is a circular cotton net with a mesh-size of 2·5 cm. It has circular pockets, about 6½ meshes deep, at the periphery. In all there are 91 pockets each having two iron cylindrical sinkers. At the apex a rope is passed through the meshes, which when pulled closes the end. While operating the net, the free end of the rope is tied down to the forefinger of the left hand and a portion of the net, near the rope, is held by the left hand. Taking grip of the net portion near the sinkers, the net is flung afar into the river, in shallow waters, dropping in a circular manner. The fish are trapped in the pockets. The net is used all the year round catching *S. phasa* and other small-sized fishes.

D. Scoop net

1. *Jali* (*Khansar, Ungee, Panti, Banjala Basiari* or *Basar*) : It consists of light bamboo poles crossing each other near one end with a triangular net laced along the two long sides. A short cross stick is fixed across the bamboo poles near the apex of the triangle. The distance between the two poles at the upper end is 1·8 to 3·6 m, the mesh of the net being 10–16 mm. The lower end of the net, just before the cross-pieces, is in some cases made up in the form of a bag to collect fish. The net is made of fine cotton yarn and is operated throughout the year, especially during monsoon season. The net can be operated by one man from a small boat in deep water or while standing in shallow water. The joint end of the two bamboo poles is held in the left hand. Taking a firm grip of the cross stick joining the two bamboo poles, it is gradually dipped in water, scooped and lifted up. *Chela* sp., small clupeoids like *S phasa* and *G. chapra* and prawns are the main catches bagged by this net.

Fishing season

General pattern of fishing season

S. phasa is caught practically all the year round. However, during south-west monsoon, when the operation of major nets like *Mahajal* etc., is suspended in the main stream on account of the excessively strong current and great rise in water level, fishermen take to the operation of *Darwari* net (a fine-meshed drag net) only. This net bags the highest percentage of *S. phasa*. This species thus continues to show up in the commercial catches during monsoon when the catches of major carps and larger catfishes go down considerably. The peak

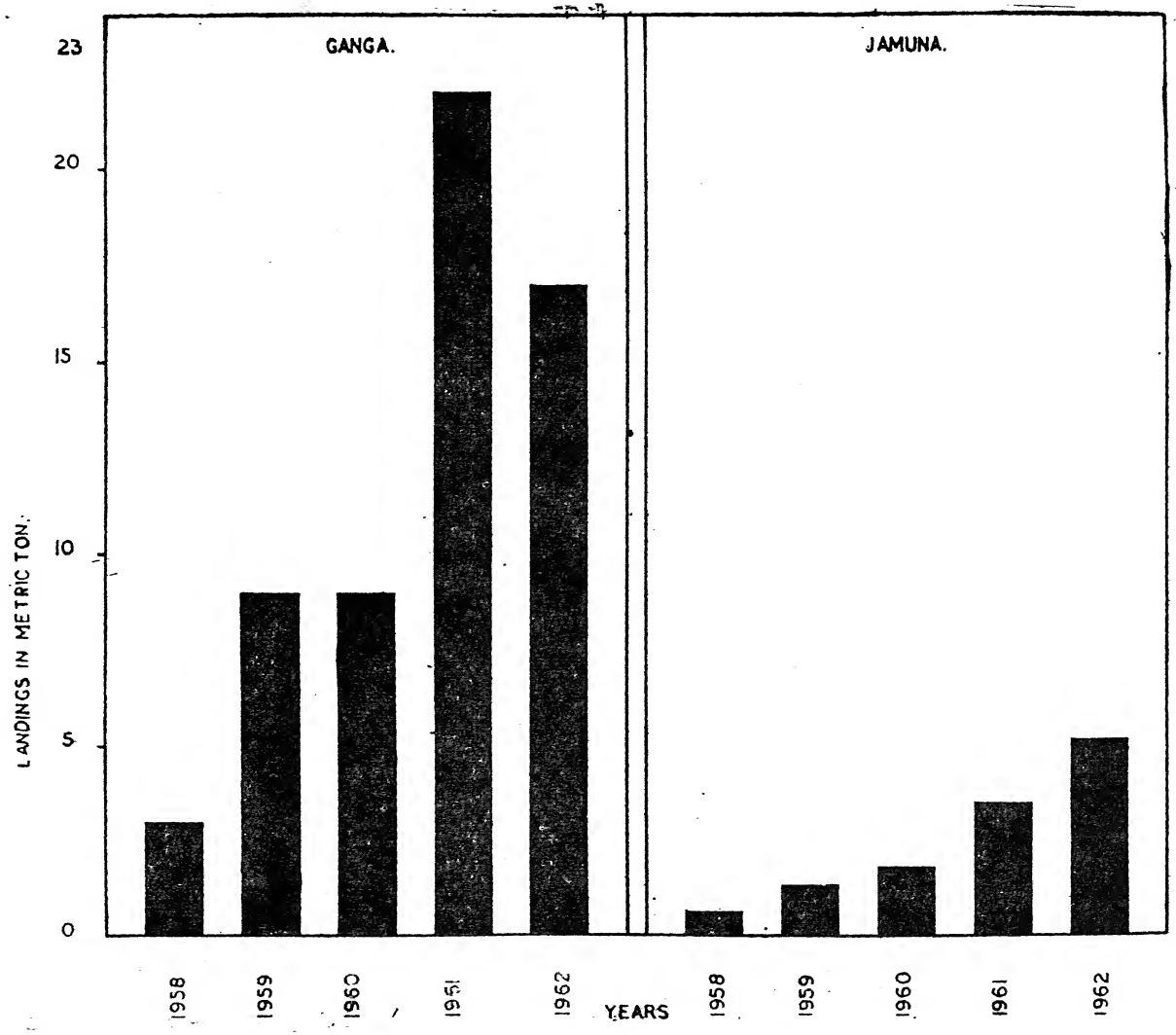

Fig. 5. Total annual landings of *S. phasa* from rivers Ganga and Yamuna.

fishing seasons for this fish are monsoon and winter as is evident from Fig. 4 wherein this species is seen crowning the landings in these months.

Variations in the time of fishing

The fishing activity in the Ganga river system is mainly dependent on weather conditions. In summers, hot winds hamper day fishing but during severe winters, day fishing is the general practice and the night fishing is almost suspended depending on the intensity of cold. Intensive fishing is stopped during monsoons due to flooded conditions of the river and fishing in this season takes place mainly in small tributaries, nallahs etc., preferably during day hours (Jhingran, 1966).

In India there is a general derth of cold storages and consumers have a positive preference for fresh fish. As such railway timings have a significant bearing on the fishing activity on account of the high demand of fish in the eastern states like Bengal. The fishes, as soon as they are captured, are brought to assembly centres, kept in baskets of varying capacities in between the layers of bounded ice and salt and immediately despatched to railway station for transportation (Jhingran, *op. cit.*). Fishing activity is also suspended during religious festivals.

Catches

For studying the seasonal fluctuations of *S. phasa* in the commercial catches and its size in commercial landings, market arrivals at important fish assembly centres were observed.

Total catch

The annual catch of *S. phasa*, as estimated at seven riparian centres for river Ganga and two for river Yamuna, during the period 1958 to 1962, averaged about 12·1 and 2·5 m tons respectively (Fig. 5). Sadiapur, on river Yamuna at Allahabad, contributed approximately 92% of the total catch of *S. phasa* from river Yamuna. Patna and Varanasi on the bank of river Ganga contributed 30·4% and 24·3% respectively to the total Ganga catch. Table I depicts the statistics of catches from different localities on the banks of Ganga and Yamuna rivers. Fluctuations in catch were not observed to be of the same magnitude for each locality in the same year. Variations in the availability of the species seemed to be affected by the local conditions rather than the factors common to the whole stock.

Seasonal catch

The catches of *S. phasa* were not evenly distributed throughout the year. The abundance of this species showed tremendous seasonal fluctuations over a period of five years. The more pronounced variability in the catch pattern was especially owing to the varying time for the onset of monsoon and consequent flooding of the rivers.

Fig. 4 shows the monthly catches from river Ganga estimated at seven selected centres situated on the bank of the river. These centres were Kanpur, Daraganj (Allahabad), Varanasi, Ballia, Buxar, Patna and Bhagalpur situated in the States of Uttar Pradesh and Bihar in the northern belt of this country. The histograms plotted for the total monthly catches at these centres on river Ganga showed a bimodal distribution. The first major peak was observed in April during 1958 and in June during 1959. In 1960 this peak shifted to March and during 1961 and 1962 in the months April and February respectively. The second peak, of a relatively higher magnitude, was noticed in October during 1958 and

in September during 1959 and 1960. In 1961 and 1962 this peak was discernible in October and November respectively.

TABLE I

Landing of *S. phasa* according to locality

Year	Landing in kg										
	River Ganga								River Yamuna		
	Kanpur	Daraganj	Varanasi	Ballia	Buxar	Bhagalpur	Patna	Total	Agra	Sadiapur	Total
1958	305	503	722	139	191	208	903	2,971	318	3,652	3,970
1959	225	603	831	184	351	474	1,165	3,833	244	1,532	1,776
1960	318	612	1,252	604	412	389	1,566	5,153	85	2,023	2,108
1961	407	819	1,678	345	655	930	2,111	6,945	398	2,317	2,715
1962	522	1,134	2,151	488	244	1,623	2,691	8,853	306	3,512	3,818
Total	1,777	3,671	6,634	1,760	1,853	3,624	8,436	27,755	17,351	13,036	14,387

The month-wise catches of *S. phasa*, recorded from river Yamuna at two selected centres situated on its bank, *viz.* Agra and Sadiapur (Allahabad), have also been shown in Fig. 4. 1958 catch showed two peaks, one spread between April and July, and the other between September and November. In 1959 there was a gradual rise in the catches from February to July while there was a drop recorded in August. In September this fall again recovered forming the highest peak of the season. The second peak was observed in December. In 1960 the first peak, of a relatively lesser magnitude, was discernible in May. The winter peak was, however, not perceptible in this year. On the other hand the most prominent peak was seen during August. In 1961 the first peak appeared in June and the second peak in October. 1962 showed a clear demarcation between the first and the second peaks, the former appearing in July and the latter in November.

Thus, significant variability in catches from month to month occurred and the period of the maximum abundance of the species was also not found to be stable.

Catch composition

The system of market measurements provided some information on the size composition of the *S. phasa* stock. It was considered desirable to examine the data under the following two heads with a view to finding out if a change in the size composition of the marketed stock took place.

Annual catch composition

The annual catch composition of *S. phasa* from 1958 to 1962 at Sadiapur fish assembly centre, Allahabad, is shown in Table II. During 1958 the modal group of the total fish landed was observed at 165 mm. It shifted to 125 mm in 1959 and 85 mm in 1960, 1961 and 1962. According to Jhingran (1961), 50% of female *S. phasa* mature at 190 mm which implies that most of the fish caught are still immature or just attaining maturity. Thus, an examination of size distribution of the catches, delineated in Fig. 6, indicates that a considerable percentage of *S. phasa*, landed at Sadiapur fish assembly centre, Allahabad, is undersized.

TABLE II

Market measurement of *S. phasa* during different years

Size range	1958	1959	1960	1961	1962
31– 40	2	14	2	..	3
41– 50	12	44	12	..	6
51– 60	8	27	4	..	14
61– 70	6	12	24	4	54
71– 80	8	73	34	31	191
81– 90	33	11	52	58	383
91–100	76	22	60	56	224
101–110	69	87	40	45	165
111–120	55	105	34	35	135
121–130	83	197	32	37	216
131–140	99	191	33	41	163
141–150	113	63	26	35	179
151–160	122	79	22	48	207
161–170	164	40	14	42	221
171–180	118	28	12	42	214
181–190	82	72	10	48	180
191–200	95	65	7	42	34
201–210	83	83	7	18	183
211–220	44	128	11	23	186
221–230	50	110	17	16	158
231–240	55	88	9	10	132
241–250	43	97	4	4	87
251–260	39	103	6	7	45
261–270	25	78	8	7	28
271–280	14	54	6	8	33
281–290	7	34	5	2	28
291–300	12	11	1	2	7
301–310	3	18	3	4	9
311–320	2	5	1	1	2

Seasonal catch composition

Table III shows that the proportion of undersized fish (Juveniles) in the market tends to increase from May and attains a peak in September when the fish from age-group II and above are poorly represented in the catches. The age-group I is most poorly represented from August to October. This may be attributed to the probability of the small fish of age-group II growing past the 85 mm length by the end of December and the failure of large fish of age-group I to enter this age-group in any significant quantity until July. The fish of age-group II (mean length 121·9 mm) are well represented throughout the year but especially so in January and from July to December. Fishes, larger than those of age-group II are few from August to October but show highest concentration during January to June and November. The proportion of age-groups VII and VIII is negligible in the catches.

TABLE III

Size composition of monthly catches of *S. phasa* at Sadiapur, Allahabad as depicted by the data pooled for the years, 1958–1962

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Total
31-40	–	–	–	–	–	–	2	–	–	–	1	–	3
41–50	–	–	–	–	2	–	5	–	5	–	2	–	14
51–60	–	–	3	–	5	1	3	3	7	2	1	–	25
61–70	1	–	4	–	31	2	8	54	24	10	2	–	136
71–80	3	–	5	2	48	34	11	99	41	37	4	6	290
81–90	4	–	16	3	56	76	23	144	117	45	9	4	497
91–100	28	–	8	1	26	44	16	95	82	42	12	7	361
101–110	30	–	16	6	11	11	50	29	28	27	7	30	245
111–120	19	3	19	3	10	14	41	25	20	28	15	53	250
121–130	16	4	17	29	14	17	46	8	28	33	11	52	275
131–140	19	7	17	27	17	27	15	7	24	29	20	17	226
141–150	23	6	13	30	28	37	12	5	19	35	12	15	235
151–160	30	17	40	28	30	54	35	15	8	20	16	19	302
161–170	23	22	40	55	39	61	17	9	8	28	12	14	328
171–180	12	17	42	47	53	41	21	11	5	25	16	18	308
181–190	16	16	20	43	24	52	24	24	7	17	28	11	282
191–200	7	19	31	18	21	35	32	8	17	9	31	11	239
201–210	9	11	17	16	13	43	28	14	24	12	50	7	244
211–220	11	13	7	21	18	41	34	18	18	10	52	13	256
221–230	14	10	25	9	8	28	25	21	9	6	69	4	228
231–240	6	8	7	11	5	28	20	12	12	9	47	6	171
241–250	5	7	11	8	9	17	6	9	4	10	37	3	132
251–260	4	8	16	9	4	15	3	6	4	16	38	10	127
261–270	5	10	9	14	2	11	8	2	3	17	26	3	110
271–280	4	3	15	13	14	6	2	8	1	5	29	7	107
281–290	–	2	13	6	5	13	–	6	–	4	18	6	73
291–300	–	1	5	5	4	2	–	2	–	1	13	2	35
301–310	–	1	1	2	2	1	–	1	–	–	8	2	18
311–320	–	–	–	1	1	–	–	1	–	–	2	–	5
	289	185	417	407	500	711	477	636	515	477	598	320	5532

Discussion

Fishing operations may be described as human intervention in a population of individuals, purporting a type of mortality—the fishing mortality. In addition to their economic significance, the fishing operations also help in maintaining a balance between the full reproductive power of the population and the restriction which the population itself imposes upon that power (Kesteven, 1850). However, by indiscriminate fishing, when the removal from the stock exceeds the replenishment by reproduction of its components, the balance between the reproduction and the fishing mortality is offset and the stock ultimately suffers depletion. The judicious management of a fishery aims at drawing a catch which is optimum in size and composition and prevents depletion of the stock. An optimum catch

is defined as that catch which may and should be taken from a population of fish in order that the power of the population as a reproducing and growing entity may be brought and held at its maximum expression (Kesteven, *op. cit.*). The optimum catch can be obtained through restrictions on the type and quantity of gear, time and place of fishing, the catch of certain groups, and direct limitation of the total catch.

S. phasa, largely because of its comparatively small size, is not regarded as highly economically important fish especially in comparison with the more abundant major carps and catfishes which attain much bigger sizes. Nevertheless, being a marketable fish, it has positive nutritive and other economic values and can play a more significant role in the national food economy if its fishery is developed. The larger specimens of this fish are frequently transported from Allahabad to centres of high fish consumption like Calcutta where there is always a ready public demand. During southwest monsoon months June to September, when in the flooded rivers fishermen are unable to operate their nets in the greatly enhanced depths and the torrential current of the main stream for catching the more economic varieties of riverine fish, *S. phasa* steps up to enjoy a fairly high commericial rank. At this time of the year they fetch an excellent price.

Despite many potential uses and growing status of this species, very little is so far known about the magnitude of the fishable stocks, the intensity of fishing and the fluctuations in the fishery. In fact, the anchovies have specially been neglected by fishery biologists in India and there is little published information thereon as compared to their Australian and American counterparts where the anchovies have established themselves as important fisheries and their products are variously used for canning, salting, plastic making, oil meal reduction and bait, etc.

In commercial operations a large variety of nets are used to capture fish. Most of these nets are selective upon the natural population which they exploit with the result that the catches taken by these nets do not give a true representation of the population from which they were drawn. Such catches show abundance of certain age-groups and consequently a paucity of others. Most of the nets used to capture *S. phasa* are not appreciably selective to size of fish though their meshes vary a great deal. Whether these nets do exercise any selective action is a question that has not been thoroughly analysed. However, Saxena (1965) observed that in drag nets in general there is a lower limit to the size of the fish retained. Detailed studies on the selectivity of nets for *S. phasa* have not yet been made.

The catch per unit of effort has been taken as an index of the abundance of fish stocks (Russel, 1942). This index is a direct measure of availability provided fishing intensity does not greatly vary. In the Ganga river system, a village-wise inventory of fishermen, boats, nets, etc., was conducted in 1957 by the Allahabad Substation of the Central Inland Fisheries Research Institute in some of the riparian districts with a view to evolving a sampling technique for estimating total effort and gear-wise catch per unit of effort as a measure of abundance of fish. But on account of very diffused and scattered nature of inland fishing industry, lack of fixed landing grounds and hours of landing, completely unstandardised state of fishing gear, very diverse trade practices and lack of effective licensing system of operatives, craft, tackle, etc., rendered the adoption of even sample survey difficult (Jhingram, 1966).

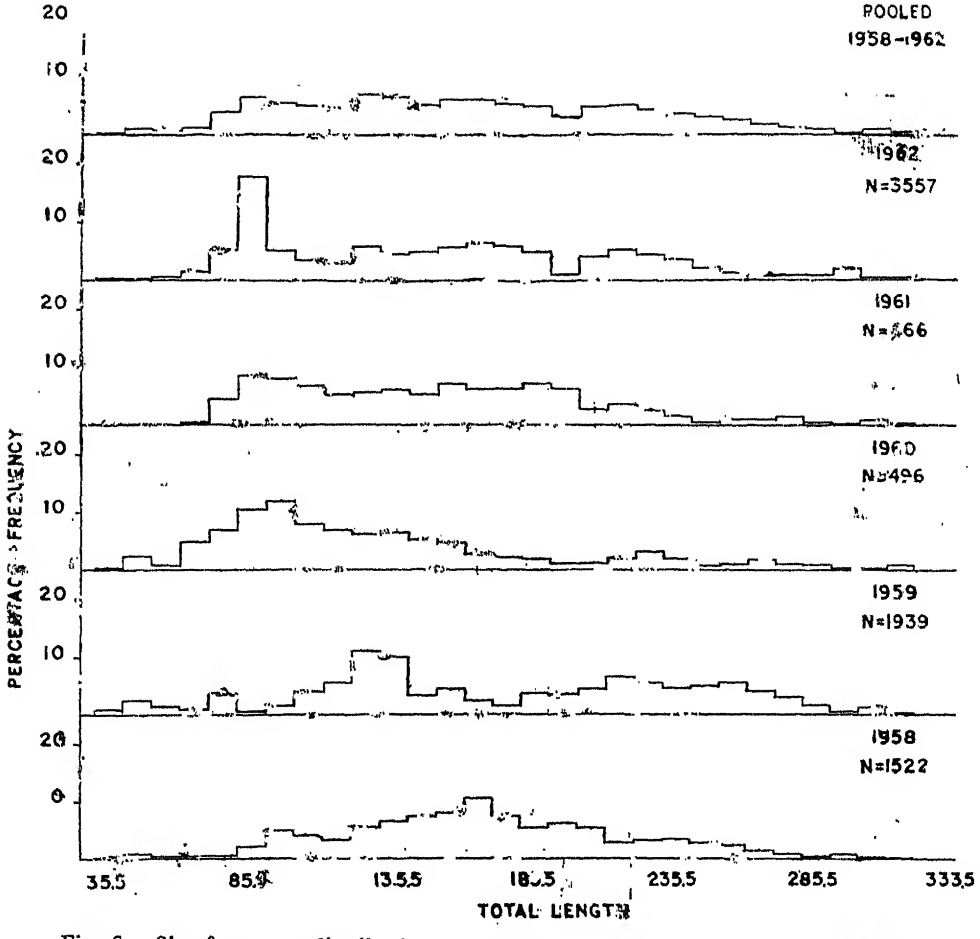

Fig. 6. Size-frequency distribution of *S. phasa* in the commercial catches at Sadiapur, during 1958–1962.

Burkenroad (1948) attributed major fluctuations in fish abundance to fluctuating envrionmental conditions. Kesteven (1950) listed the following factors causing fluctuations in a fishery :

I. Fluctuations due to variation in accessibility :
   (*a*) Variations in the condition under which fishing is conducted.
   (*b*) Variations in the abundance with which the fish occurs in the area.

II. Fluctuations due to real changes in the abundance of the stock :
   (*a*) Variations in the numbers of the population.
   (*b*) Variations in the composition of the population, producing changes in total weight of stock.

Over the five-year period of observation, the trend of the total catch of *S. phasa* was found to be upwards. A perusal of Table I reveals that none of these catch data provides any evidence of a sustained decline in the abundance of *S. phasa* at any stage of the fishery. On the contrary the trends in catch are either upwards or stable or irregular in a manner suggestive of the effect of factors like natural fluctuations, weather, intensity of fishing, and especially that of demand. As has already been mentioned earlier, *S. phasa* is held only in a limited esteem by the consumers and the abundance of the fish is rather inversely related to the availability of the more economically important fishes like major carps and larger catfishes. However, in view of the paucity of other evidences, it may be concluded that the fluctuations in the fishery of *S. phasa* may be attributed to factors like competition with other fishery (that of major carps and larger catfishes) and the demand.

Kesteven (1950) remarked that every fish should be given at least one or two chances to spawn before it is caught. This, he described :

> "As an early method for indicating the level at which 'protection' should operate for a species being fished".

A sizeable percentage of juvenile (mostly 0–and first year) *S. phasa* are also marketed during the months April or May to September. It is significant to note that the fish has the maximum growth between the first and second years of its life which has a considerable bearing on the practical fishery management. Hence, any large scale exploitation of this fish of the age-groups I and II, as depicted by the modal-size of the total catch landed (Fig. 6), is likely to affect the fishery and lower the yield level ultimately leading to depletion.

In view of the fact that the size distribution of *S. phasa* in the commercial catches has not changed in the face of varying intensity of fishing, it may be concluded that for *S. phasa* there is an 'uneconomic fishing' and these fishes are caught at too small a size, when most of them are still immature, not having attained even their optimum growth.

Summary

Market measurements, observations on fishing operations and estimation of fish landings at selected riparian centres along the rivers Ganga and Yamuna revealed that *S. phasa* is caught in a wide variety of nets differing in size, mesh and number of pieces. No specific net has so far been designed to catch this species exclusively. Fishing season are mainly monsoon and winter. During other seasons efforts are directed more towards fishes of high economic importance like major carps and larger catfishes when they are available.

The trends in the total catch of this species appeared upwards, stable or irregular. The whether condition, especially the onset of southwest monsoon and

the consequent direction of fishing effort towards more economic species is the major factor that determines the magnitude of catch. The size composition of this species in the commercial catches showed only little variation over the past five years suggesting an uneconomic fishery.

The fisheries of *S. phasa* is at present not prosperous, having suffered a lot on account of competition with other flourishing fisheries. However, the population can stand greater exploitation than it presently endures.

A large proportion of catches consists of fish either immature or just maturing. The management programme for this species should be formulated based on the ideas :

(*i*) that the fish should be given at least one chance to spawn before being caught.

(*ii*) that the fish should be allowed to grow larger so as to give a greater annual yield in weight.

Acknowledgement

The encouragement and helpful suggestions received from Dr. V. G. Jhingran, Director, Central Inland Fisheries Research Institute, Barrackpore are greatfully acknowledged.

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The Mouthparts and Feeding Mechanism of the Collembolan *Tomocerus longicornis* (Müller) (Tomoceridae)

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Our knowledge of the biology of Collembola, specially its feeding habits and the mechanism of food intake and digestion, is meagre and in certain respects erroneous. Folsom (1899) was the first to describe in some detail the mouthparts of *Orchesella cincta*. He was followed by Hoffmann (1905, 1908 and 1911) who gave an account of the structure and musculature of mouthparts of *Tomocerus plumbeus* and drew attention to the rotatory movements of the mandible. He also described the nerve supply to the muscles in the head. Imms (1906) gave a brief account of the mouthparts of *Anurida maritima* and the structural similarities in the different Collembolan species. Denis (1928) studied the comparative anatomy of the head of *Anurida maritima*, *Onychiurus fimetarius* and *Tomocerus catalanus*, including the mandibular and maxillary musculature of the former two and the mandibular musculature of the last species, but his description of the origin and insertion of the muscles is superficial and incomplete. Recently Tuxen (1959) has described entognathy in apterygote insects from the evolutionery point of view and included the account of the Collembolan *Onychiurus armatus* and Manton (1964) has given an account of the mandibular mechanism of *Tomocerus longicornis* while discussing "mandibular mechanisms and evolution of Arthropods. Unfortunately none of these workers have studied the mouthparts and feeding mechanism and so the need for a comprehensive study of food, feeding habits and feeding mechanism in this Order is obvious. In the present series of papers the author has undertaken such a study in four species *viz. Tomocerus longicornis, Onychiurus armatus, Friesea mirabilis* and *Neanura muscorum.*

In the present paper the anatomy of the mouthparts of *Tomocerus longicornis* together with a description of the feeding mechanism has been given. It may be noted that this species occurs in leaf-litter and feeds on soft solid food (Singh, 1964 *a, b* ; Poole, 1959).

Material and Methods

Specimens of *T. longicornis* were collected from the upper surface of the leaf litter of coniferous forest soil around Aberystwyth, U. K. They were also obtained from the decaying logs in a deciduous woodland from amongst mosses, at the base of bushes, ferns and undergrowth. For dissection purposes, they were fixed in hot Dubosq-Brasil fluid for three hours and then placed in 90% alcohol before being transferred to 50% lactic acid for twelve hours at 40°C for clearing. After this treatment, the mouthparts were clearly visible and were dissected out with fine needles and microscalpels made from safety razor blade. Permanent mounts of mouthparts were made in polyvinyl alcohol 'A' (Salmon, 1949) and lignin pink was employed as stain. The relationship of the muscles to the mouthparts was

studied under a phase contrast microscope. Further probing and dissecting, if necessary, were carried out with a Leitz micro-manipulator.

Details of the structure of the mouthparts and their associated musculature were elucidated from a study of serial sections. The head was fixed in Carnoy's fluid for 2½ hours at 40°C, cleared in Amyl acetate for atleast eight hours then placed in toluene for half an hour before transferring to paraffin wax with ceresin. (Steedman, 1960). For gross anatomical studies 4 to 15μ thick paraffin sections and 25μ thick celloidin sections, according to the method of Dennell (1940), were cut. Mallory's triple stain was mainly used for anatomical studies.

Observation and Discussion

A. The head and the arrangement of the mouthparts

The head of *T. longicornis* does not show segmentation. It is pear-shaped and slightly compressed dorso-ventrally. The head capsule is extended in the form of a cone at the end of which lies the opening of the pre-oral cavity. This is referred to as the hypostome. The mouthparts are prognathous and entognathous. They are enclosed in the cavity formed by the fusion of the lateral margins of the labium with the head (Folsom, 1900 ; Snodgrass, 1952). The cavity can be divided into two parts, the gnathal pouch which contains the posterior parts of the mandibles and maxillae and the pre-oral cavity which contains the hypopharynx and the anterior parts of the mandibles and maxillae. The free anterior parts of the mandibles lie above and parrallel to the hypopharynx, and their posterior parts or the shafts to which mandibular muscles are attached, lie suspended dorso-ventrally from the wall of the gnathal pouch by thin, flexible, folded, chitinous dorso-lateral ridge (*see* figs. 3 and 8) mesially, while the dorsal and ventral margins of the mandibular cavity continues as ample arthrodial membranes (fig. 9). The posterior end of each mandible is suspended from the lateral head wall by the mandibular suspension (fig. 1 and 3). The frame work of the maxilla lies parallel to the mandible. Its anterior part or head moves between the dorsal surface of the free part of the lingua and the ventral surface of the free part of the superlingua so that the fans on the maxilla head interlock with the longitudinal rows of bristles on the lingua and superlinguae. The posterior portion of the maxilla on which the muscles providing the motive force during feeding are inserted, lies in the gnathal pouch ventral to the mandible (fig. 8 and 9).

The hypopharynx occupies a median position in the pre-oral cavity (fig. 7). Posteriorly its dorsal surface forms the floor and sides of the cibarium and finally ends at the opening of the oesophagus. The space enclosed between the epipharynx dorsally and the labium ventrally is known as pre-oral cavity and opens to the exterior by a transverse opening. While feeding, the anterior parts of the mandibles, maxillae and hypopharynx can be protracted through the opening of the pre-oral cavity. This is a characteristic of entognathous insects.

The mouthparts and their musculature

Mandibles : Each mandible in *T. longicornis* is a stout structure modified for dealing with relatively larger food particles. Functionally it can be divided into two parts—an anterior part (anterior lobe) which lies free in the pre-oral cavity and is directly concerned with the manipulation of the food, and a posterior part (the shaft) to which are inserted the mandibular muscles. The incisor teeth are situated at the anterior end of the mandible and are used for scraping or cutting the food surface. These are of equal size and are arranged in a linear fashion. The right mandible has five incisors and lies slightly dorsal to the left mandible which has only four teeth. The molar plate (figs. 1 and 2) is a crescentric, curved

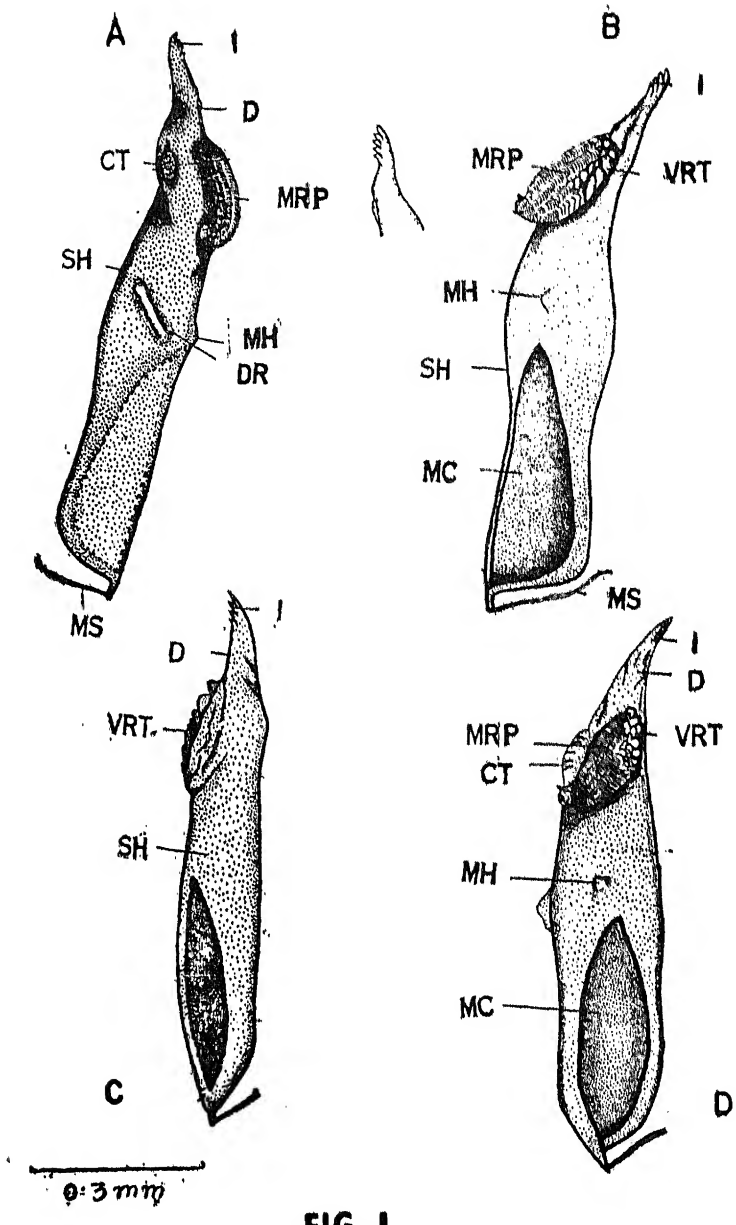

FIG. 1

Fig. 1. (*a*) Dorsal view of the left mandible.
(*b*) Dorsal view of the right mandible showing the five incisor teeth.
(*c*) Ventral view of the left mandible.
(*d*) Dorso-lateral view of the left mandible.
(*e*) Mesial aspect of the left mandible.

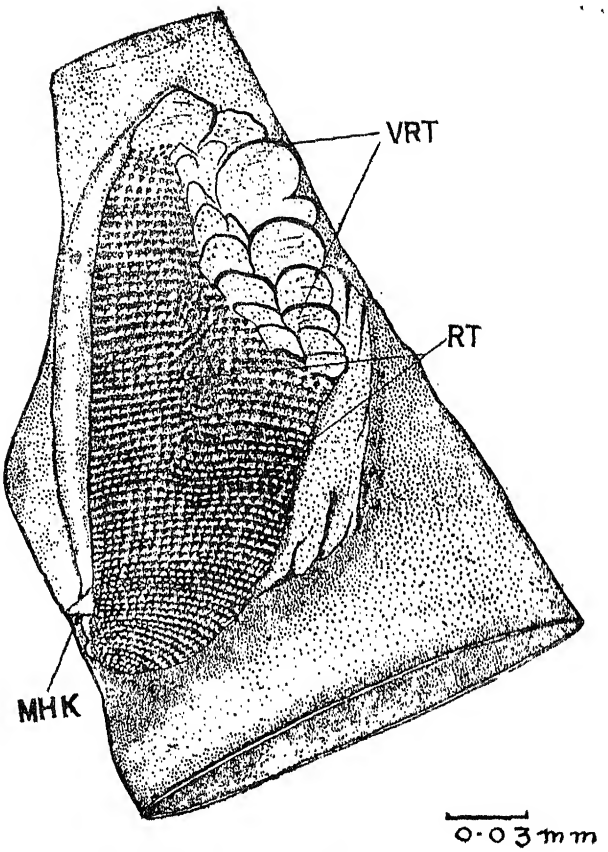

FIG. 2

Fig. 2. Mesial aspect of the molar plate of the left mandible of *T. longicornis*.

and convex area lying mesially on the anterior lobe of the mandibles. The crescentric shape of the molar plate follows the curved shape of the cibarium. The molar plates have a ventral region bearing large teeth which are arranged in two rows. Postero-dorsally there is a mandibular hook (fig. 2) which lies between the lateral folds of the epipharynx and the oral valve (figs. 7 and 6). The region of the molar plate between the hook and the ventral rows of the teeth is covered with teeth arranged in undulating transverse rows. (fig. 2).

The posterior part of the mandible is hollow and has been referred to as the mandibular cavity which opens mesially in a triangular fashion for allowing mandibular muscles to enter and insert.

The mandibles of *T. longicornis* show two types of movements—protraction which are accompanied by counter-rotation, and retraction combined with rotation. Rotation is a movement in which the molar surface of the mandible moves mesially and upward, whilst during counter-rotation it moves laterally and downward. The numbering of the musculatures used agrees with that of Manton (1964).

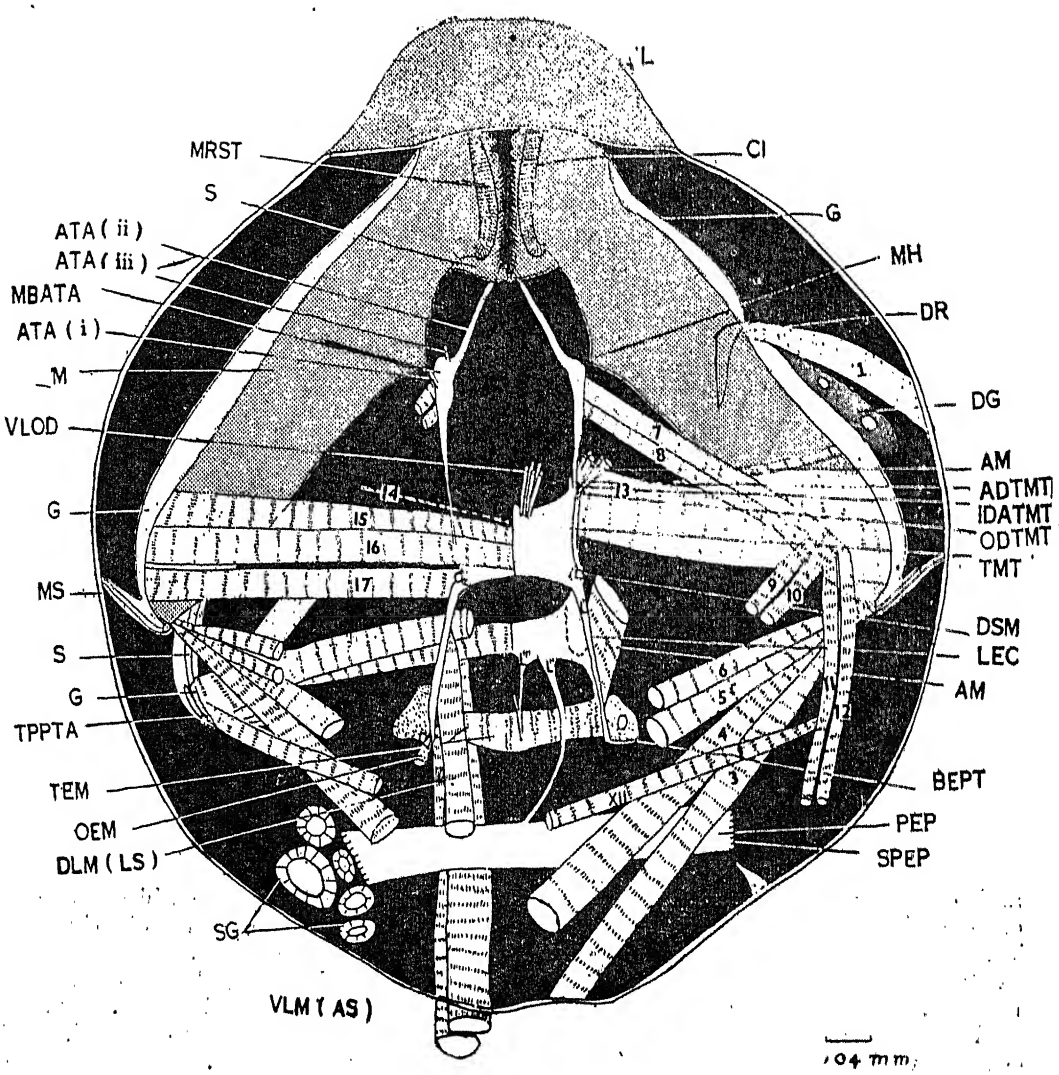

FIG. 3

Fig. 3. Diagramatic horizontal section (reconstructed) of the head of *T. longicornis* showing the mandibular muscles viewed from above, the right side representing a more dorsal level than the left. Endoskeletal structures and maxillary muscles have been incorporated to show their relative positions.

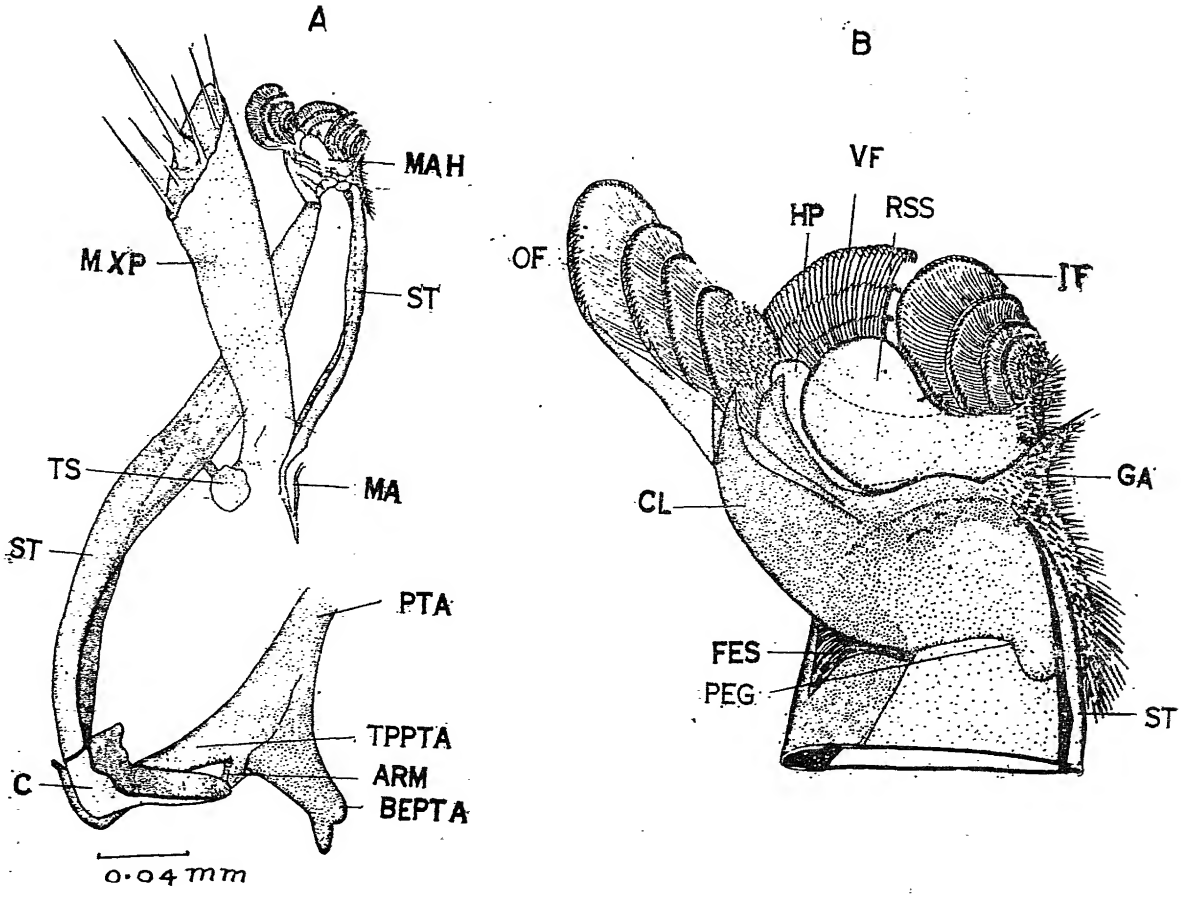

FIG. 4

Fi g. 4. Mouthparts of *T. longicornis*.
(*a*) Dorsal view of the right maxilla head.
(*b*) Dorsal view of the right maxilla. A portion of the posterior tentorium has been incorporated to show their relative positions.

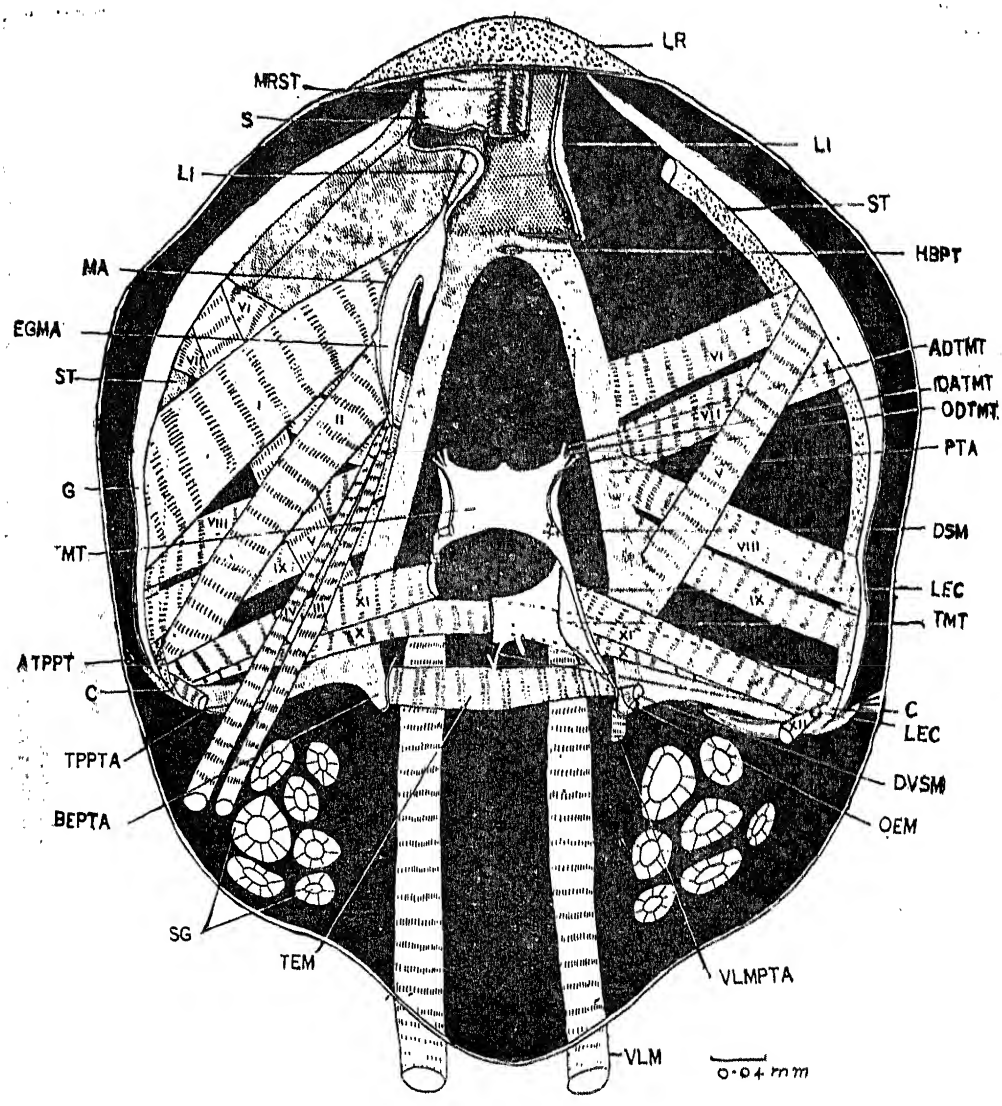

FIG. 5

Fig. 5. Diagramatic horizontal section (reconstructed) of the head of *T. longicornis* showing the maxillary muscles viewed from above. The left side is at a more dorsal level than the right. The endoskeletal structures and the ventral longitudinal muscles have been incorporated in the diagrams although they are at a slightly different level.

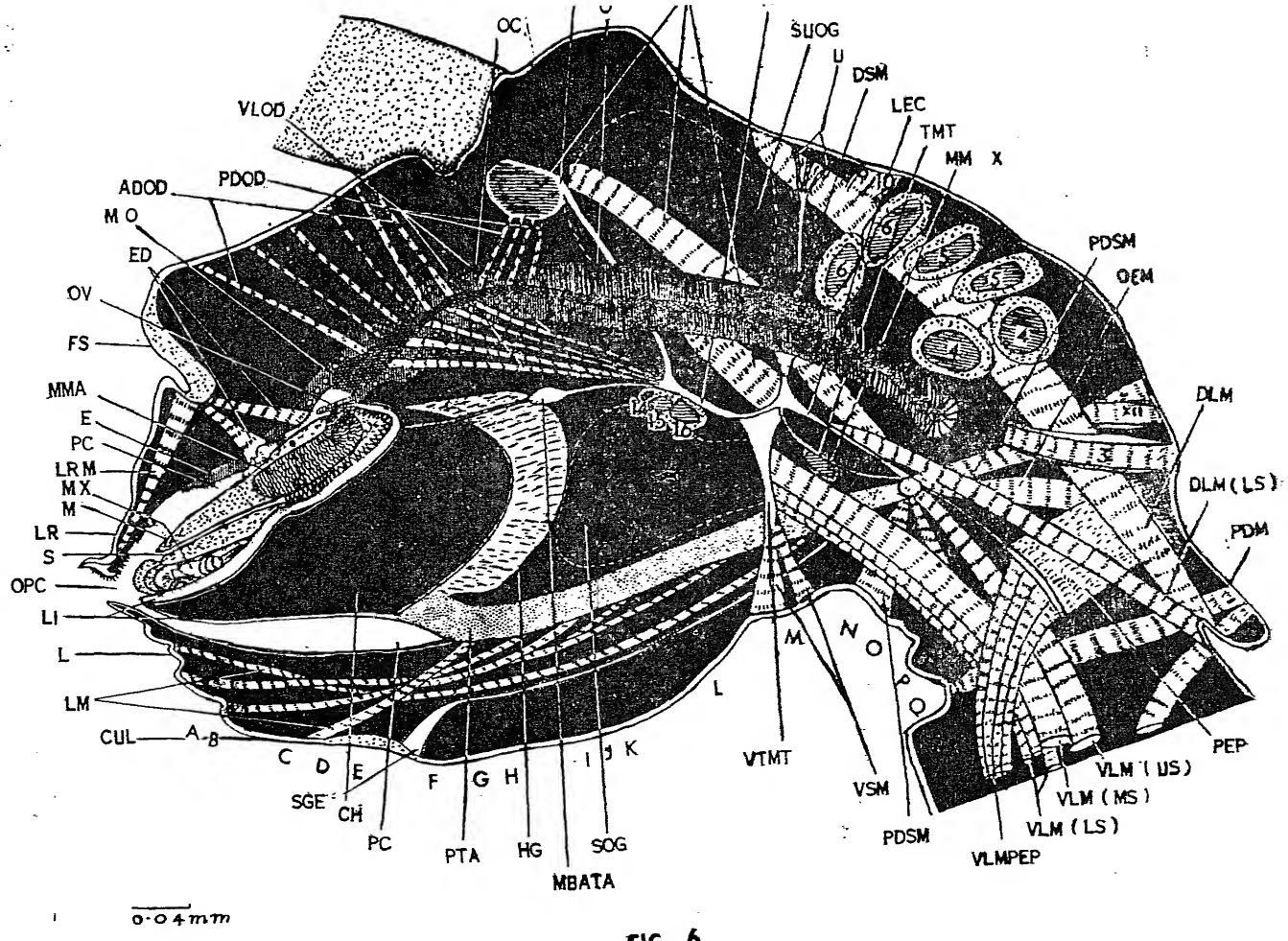

FIG. 6

Fig. 6. Reconstruction of a sagittal half of the head of *T. longicornis* viewed from the mid line. The levels of subsequent transverse sections are marked by letters A-Q.

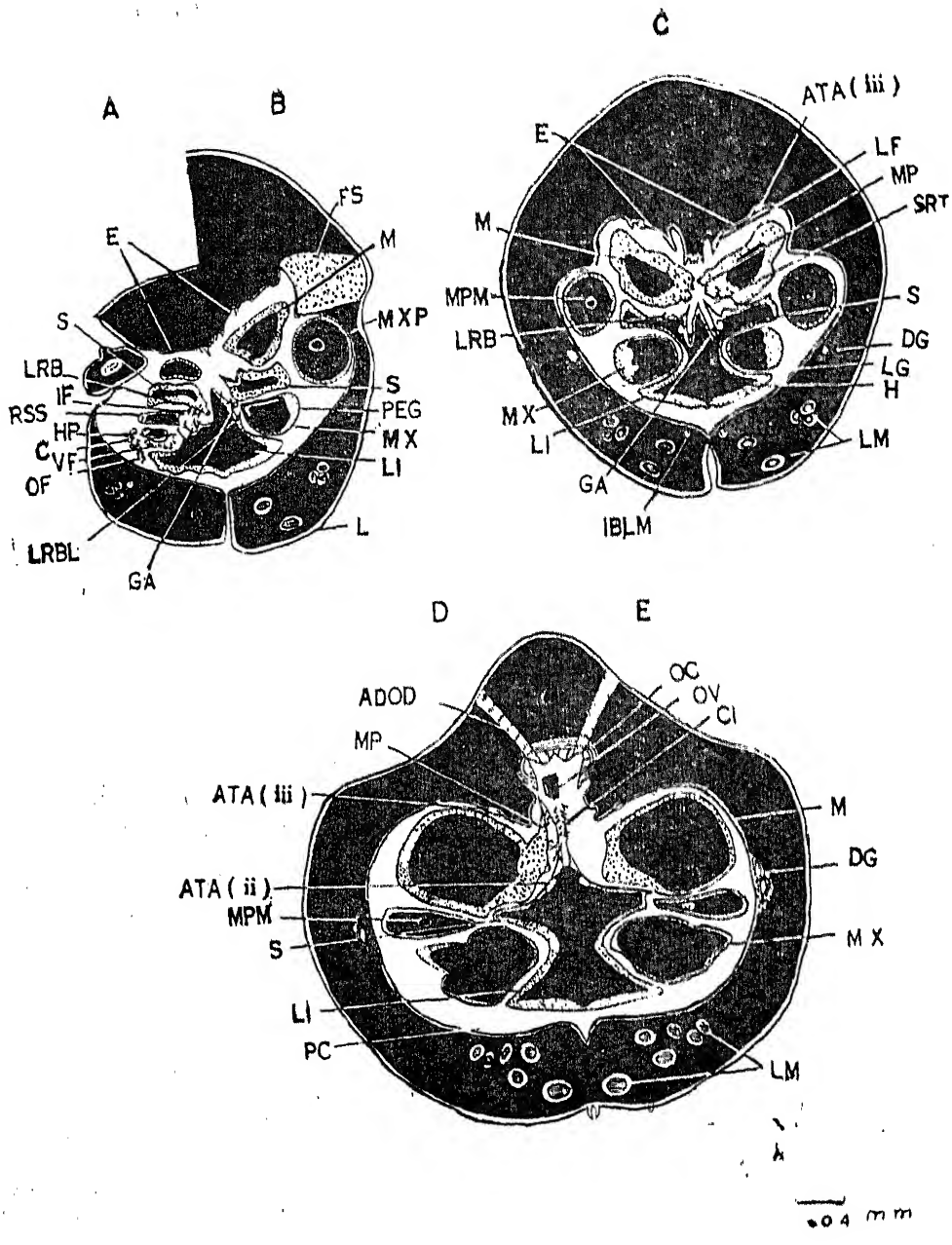

FIG 7

Fig. 7. Diagrammatic T. S. of halves of the head of *T. longicornis* passing through levels A, B C, D and E (see Fig. 6).

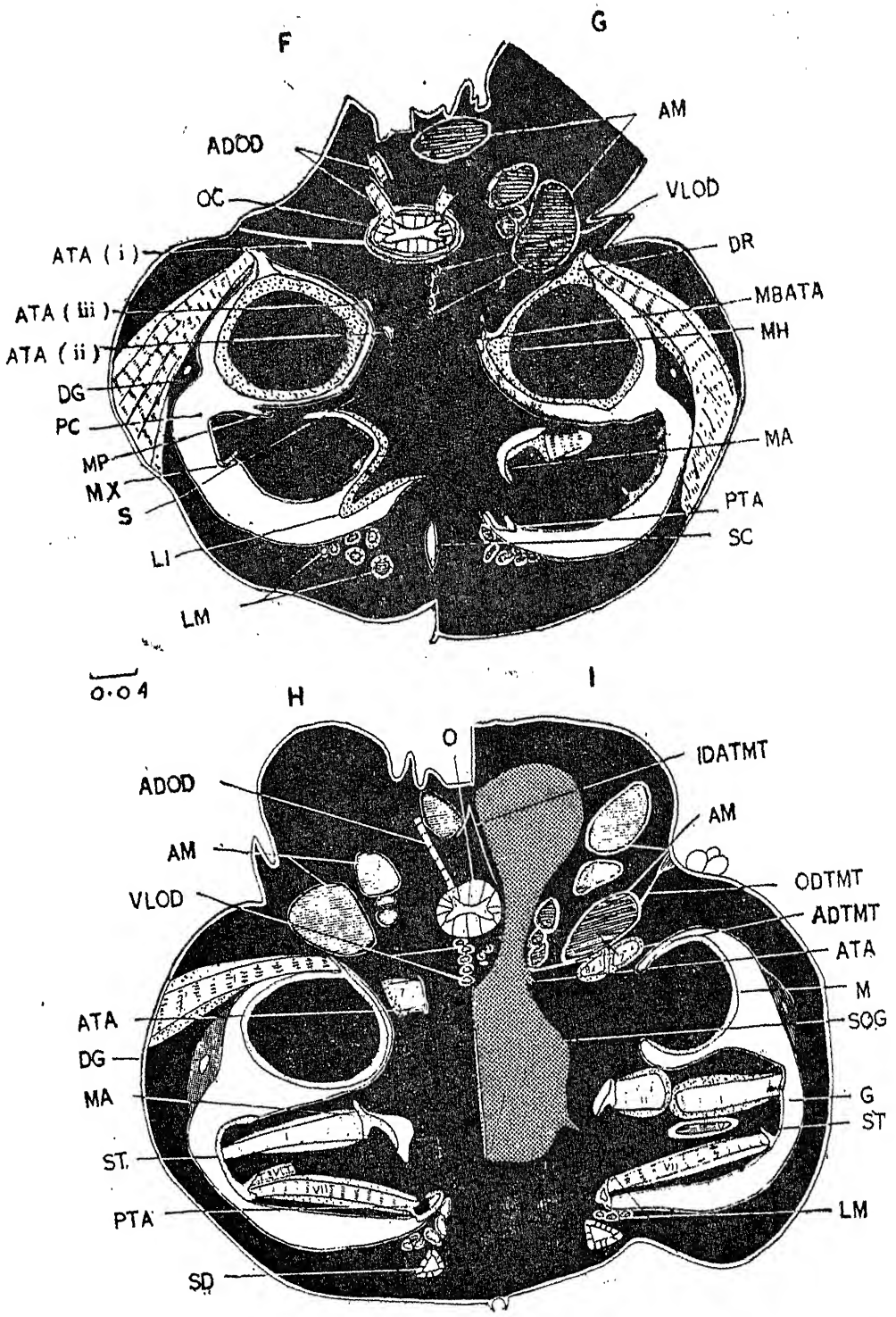

FIG. 8

Fig. 8. Diagramatic T. S. of halves of the head of *T. longicornis* passing through levels F, G, H, and I. (see Fig. 6).

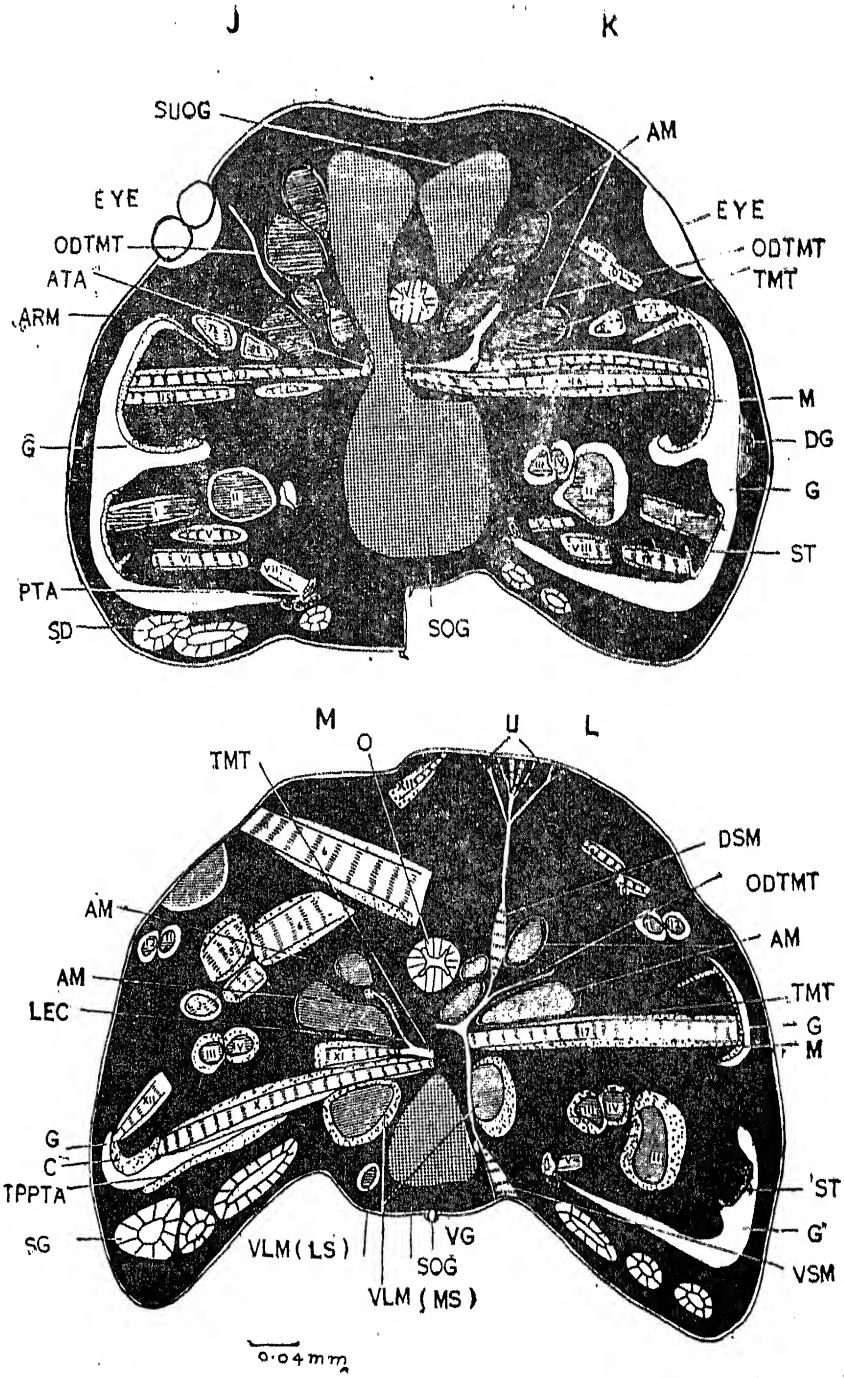

FIG. 9

Fig. 9. Diagramatic T. S. of halves of the head of *T. longicornis* passing through levels J, K, L and M (see Fig. 6).

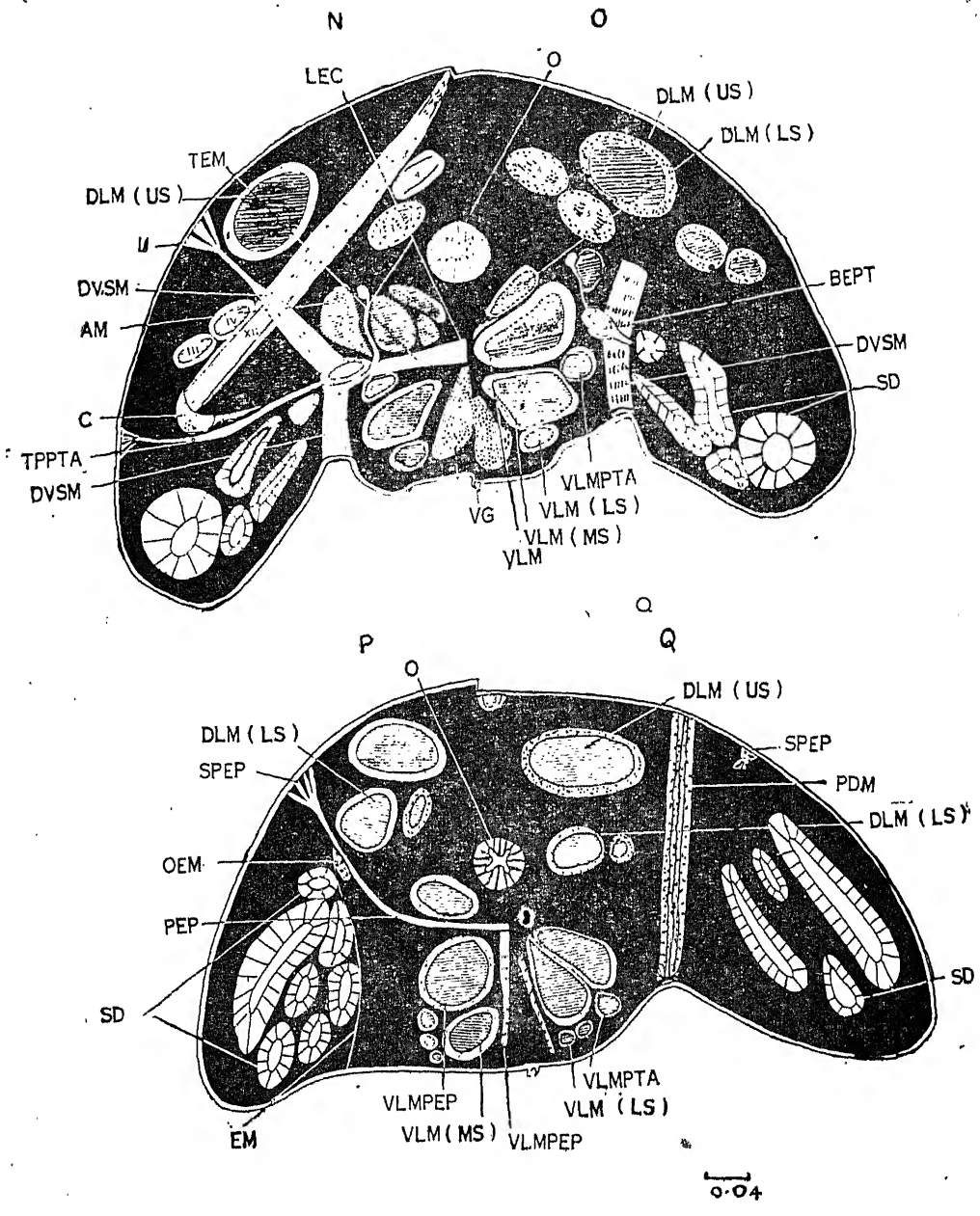

FIG. 10

Fig. 10. Diagramatic T. S. of halves of the head of *T. longicornis* passing through levels N, O, P and Q (see Fig. 6).

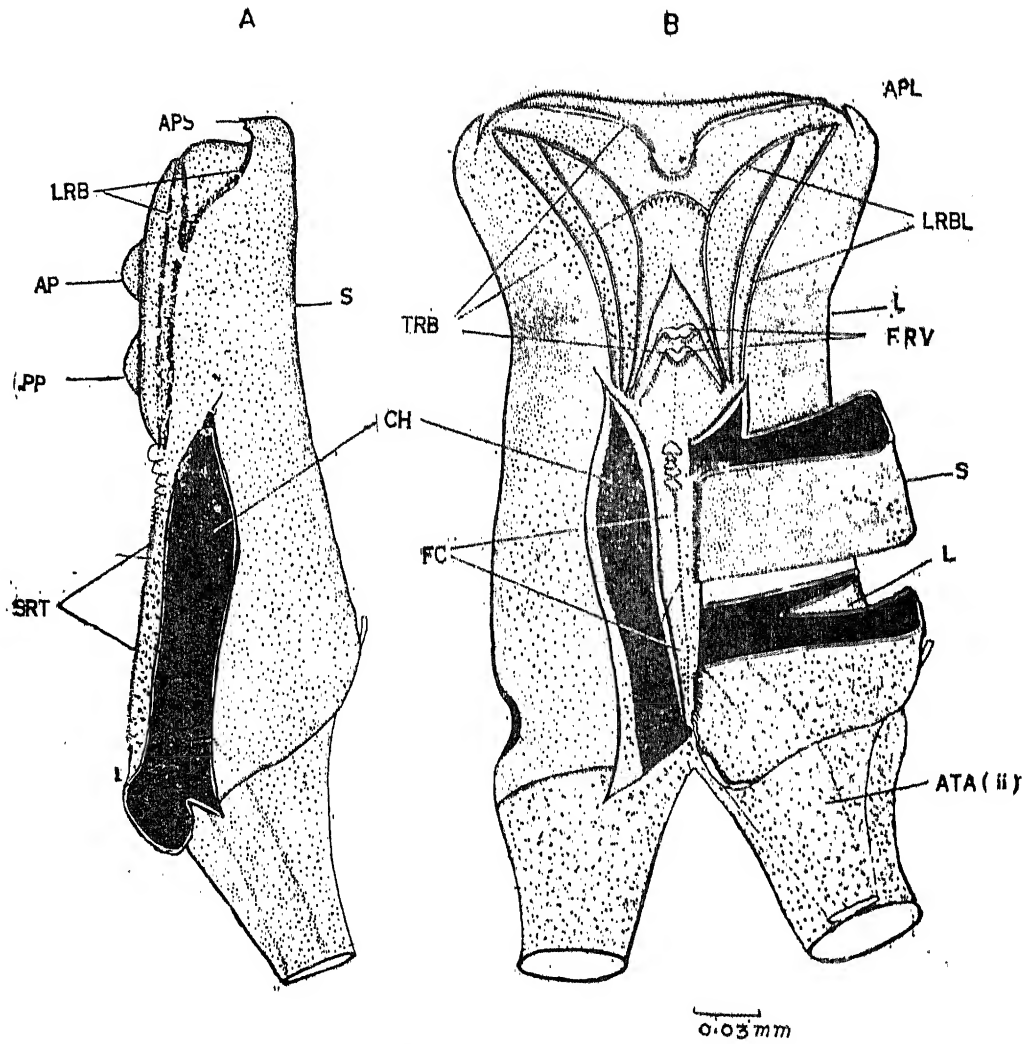

FIG. 11

Fig. 11. Dorsal view of the hypopharynx of *T. longicornis*. The left superlingua has been removed from the hypopharynx to show its ventral aspect and to reveal the dorsal aspect of the lingua.

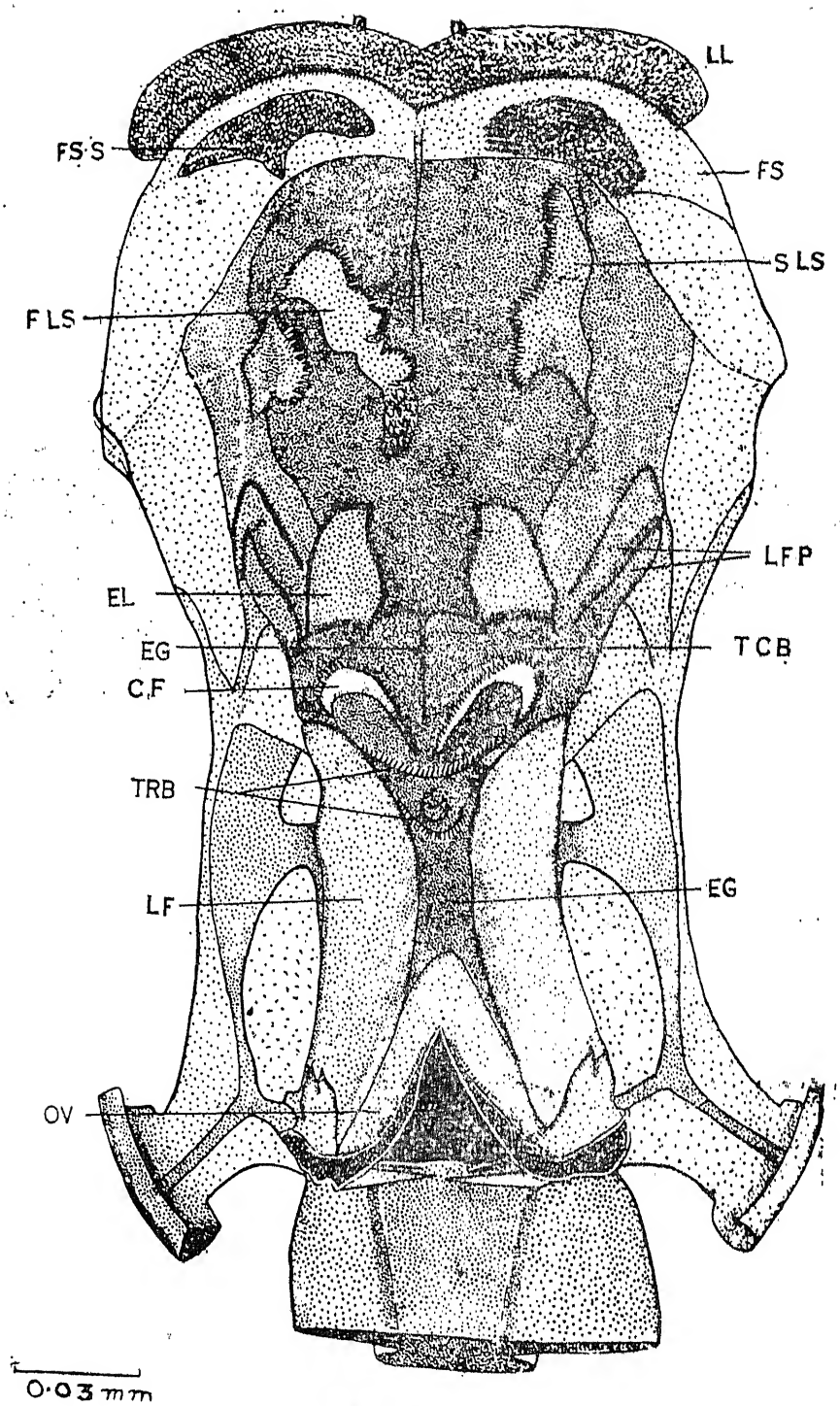

FIG. 12

Fig. 12. Inner aspect of the epipharynx of *T. longicornis*

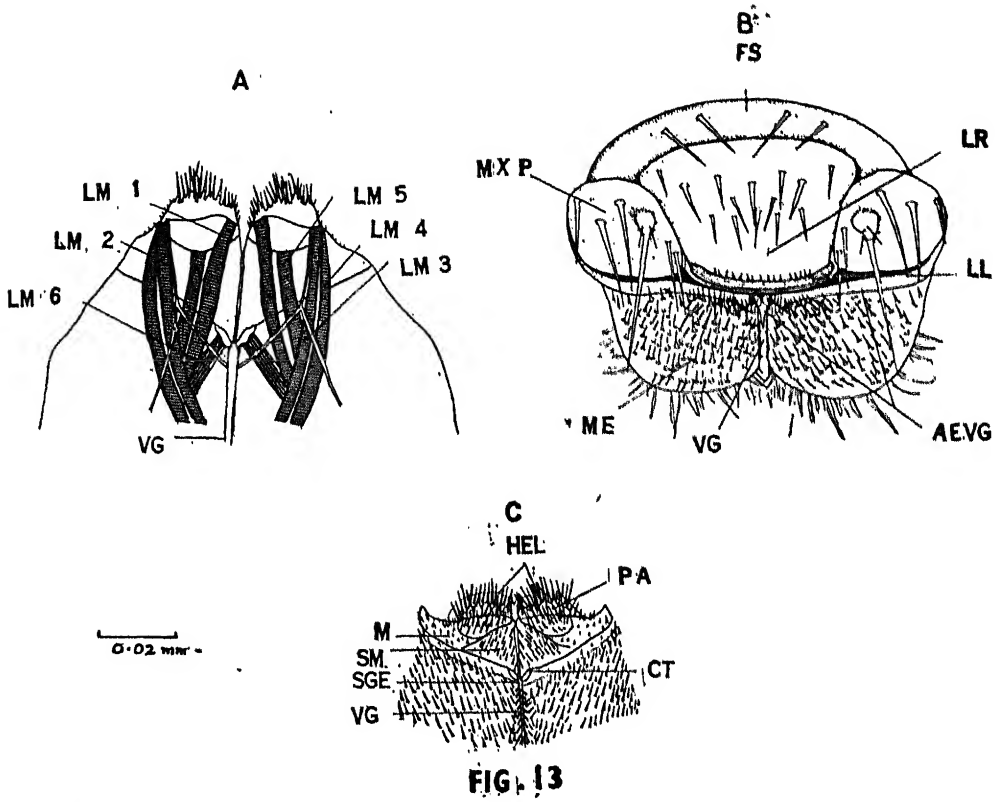

FIG. 13

Fig. 13. Pre-oral cavity and labium of *T. longicornis*
(*a*) External aspect of the opening of the pre-oral cavity.
(*b*) Internal aspect of the musculature of the labium
(*c*) External aspect of the labium.

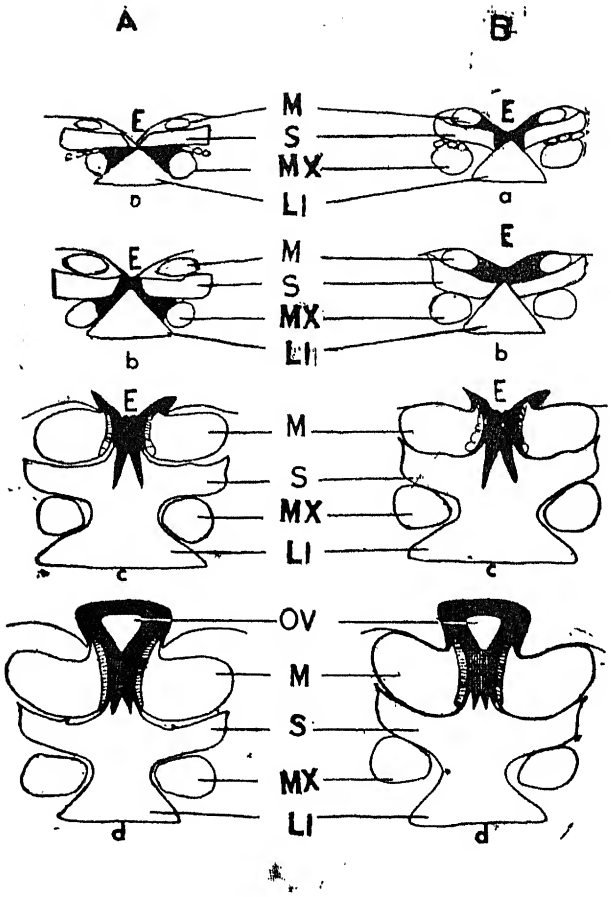

FIG. 14

Fig. 14. Diagrams showing the food meatus in T. S. during feeding of *T. longicornis* on different types of food. The path of the food is stippled.
A.—Solid food.
B.—Fluid food.
(Ep=Epipharynx ; M.=Mandible ; Mx=Maxilla
Sl=Superlingua ; L.=Lingua and Ov=Oral valve.

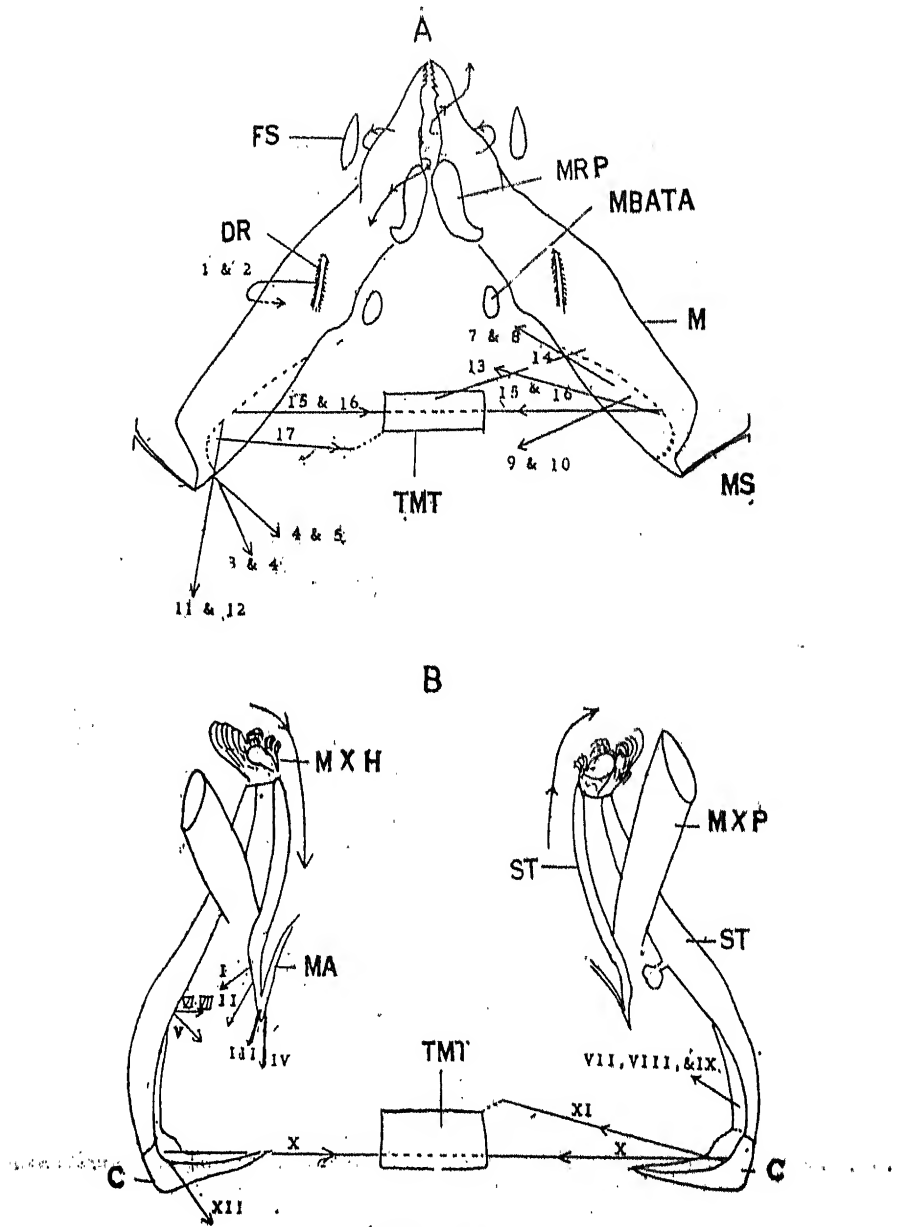

FIG. 15

Fig. 15. (*a*) Diagramatic representation of the mandibular muscles and the movements brought about by them.
(*b*) Diagramatic representation of the maxillary muscles and the movements brought about by them.

EXPLANATION OF FIGURES

A Antenna.
AM Antennal muscle.
ADTMT Anterior dorsal arm of transverse mandibular tendon.
ADOD Anterior dorso-lateral oesophageal dilators.
AEVG Anterior end of ventral groove.
AP Anterior pad.
APL Anterior promontary of lingua.
APS Anterior promontary of Superlingua.
ATA (*i*) Anterior tentorial apodeme (branch-*i*)
(*ii*) Anterior tentorial apodeme (branch-*ii*)
(*iii*) Anterior tentorial apodeme (branch-*iii*)
ARM Arthrodial membrane.
ATPPT Attachment of transverse process of posterior tentorium.
BEPTA Blind end of posterior tentorial apodeme
CH Cavity of Hypopharynx.
C Cardo.
CT Chitinous thickening.
CI Cibarium.
CF Crescentric flap.
CL Claw.
CUL Close union of labium.
D Diastema.
DR Dorso-lateral mandibular ridge.
DLM (US) Dorsal longitudinal muscles (upper sector).
(MS) Dorsal longitudinal muscles (middle sector).
(LS) Dorsal longitudinal muscles (lower sector).
DSM Dorsal suspensory muscle.
DSG Ductless Salivary gland.
DTB Dorsal tract of bristles.
DVSM Dorso-ventral suspensory muscle.
DG Ductless gland.
E Epipharynx.
EG Epipharyngeal groove.
EL Epipharyngeal lobe.
ED Epipharyngeal dilators.
EM Endoskeletal membrane.
EGMA Extension of gnathalpouch into maxillary apodeme.
FES Flattened end of stipes.
FLS Flap like structure.
FC Floor of cibarium.
FRV Food retaining valve.
FS Frontal sclerite.
FSS Field of small spine.
GA Galeal appendage.
G Gnathalpouch.
H Hypopharynx.
HEL Hyaline end of labium.
HP Hyaline plate.
HG Hypopharyngeal gland.
HBPT Hypopharyngeal bar of posterior tentorium.
I Incisor.
IBLM Inner branch of labial muscle 2.
IDATMT Inner dorsal arm of transverse mandibular tendon.
IDSM Inner dorsal suspensory muscle.
IDAMT Inner dorsal arm of mandibular tendon
IF Inner fan.
LM Labial muscles.
LM-1 Labial muscle – 1.
LM-2 Labial muscle – 2.
LM-3 Labial muscle – 3.
LM-4 Labial muscle – 4.
LM-5 Labial muscle – 5.
LM-6 Labial muscle – 6.
L Labium.
LR Labrum.
LRM Labral muscle.
LF Lateral fold.
LFP Lateral flap.
LG Lateral groove.
LL Lip of labrum.
LI Lingua.
LEC Longitudinal Endoskeletal connective.
LRB Longitudinal rows of bristles.
M Mandible.
MHK Mandibular hook.
MC Mandibular cavity.
MMA Mandibular molar area.
MH Mandibular hump.
MS Mandibular suspension.
MBATA Mandibular boss on anterior tentorial apodeme.
MA Maxillary apodeme.
MXP Maxillary palp.
MPM Maxillary palp muscle.
MXH Maxilla head.
MM Maxillary muscle.
MX Maxilla.
MN Mentum.
MGL Median gap of labium.
MRST Mesial row of superlingual teeth.
MRP Molar plate.
MO Mouth.
OEM Oblique endoskeletal muscle.
O Oesophagus.
OC Oesophageal constrictor muscles.
OPC Opening of the pre-oral cavity.
OV Oral valve.
ODTMT Outer dorsal arm of transverse mandibular tendon.
ODSM Outer dorsal suspensory muscle.
OF Outer fan.
OSBS Oral space between superlinguae.
PDM Posterior dorso-ventral muscle.

PDSM Posterior dorso-ventral suspensory muscle.

PDOD Posterior dorso-lateral oesophageal dilators.

PEP Posterior endoskeletal plate.

PEG Posterior extension of galea (Galeal extension).

PP Posterior pad.

PRS Posterior ridge of superlingua.

PTA Posterior tentorial apodeme.

PA Palp.

PC Pre-oral cavity.

RCP Row of chitinous projection.

RT Rows of teeth.

RSS Retort shaped structure.

SG Salivary gland (segmental organ).

SGE Salivary gland Exit.

SC Salivary channel.

SD Salivary duct.

SLS Saw like structure.

SH Shaft.

ST Stipes.

SM Sub-mentum.

SOG Sub-oesophageal ganglia.

SUOG Supra-oesophageal ganglion.

S Superlingua.

SRT Superlingual row of teeth.

SPEP Suspension of posterior endoskelatal plate.

TCB Transverse chitinous band.

TEM Transverse endoskeletal muscle.

TMT Transverse mandibular tendon.

TMT Transverse maxillary tendon.

TPPTA Transverse process of posterior tentorial apodeme.

TRB Transverse rows of bristles.

TS Transverse sclerite.

TSPTA Tentorial sclerotisation of posterior tentorial apodeme.

U Unstriated fibrils.

VTMT Ventral arm of Transverse madibular tendon.

VF Ventral fan.

VG Ventral groove.

VLOD Ventral lateral osophageal dilators.

VLMPEP Ventral longitudinal muscle to posterior endoskeletal plate.

VLMPTA Ventral longitudinal muscle to posterior tentorial apodeme.

VLM Ventral longitudinal muscle.

VLM(US) Ventral longitudinal muscles (upper sector).

(MS) Ventral longitudinal muscles (middle sector).

(LS) Ventral longitudinal muscles (lower sector).

(AS) Ventral longitudinal muscles (All sector).

VRBS Ventral row of bristles on Seperlingua

VRT Ventral row of teeth.

VSM Ventral suspensory muscle.

The retraction-rotation movement is brought about by muscles 1, 2, 3, 4, 5, 6, 11, 12 and 17. Mandibular muscles 1 and 2 originate from the lateral head wall and are inserted on the dorso-lateral ridge of the mandible. These muscles are rotators in function. Mandibular muscle 3 (fig. 3) originates from the posterior median head wall and inserts ventrally on the posterior end of the mandible through a thickened arthrodial membrane. This muscle functions both as a retractor and a rotator. Mandidular muscles 4, 5 and 6 originate from the dorsal head wall and insert on the posteroventral end of the mandibular cavity through a thickened arthrodial membrane (fig. 3). Muscles 4, 5, and 6, which originate on the left of the head wall, insert on the right mandible and *vice-versa* so that the two sets of muscles cross the middle line. These muscles function as rotators, but muscle 4 which has a very posterior origin also acts as a retractor. Muscles 11 and 12 originate from the postero-lateral wall of the head and insert on the dorso lateral ridge of the mandibular cavity. These muscles function purely as retractors. The mandibular muscles 17 is also concerned in the retraction movement of the mandible and it originates from the base of the longitudinal endoskeletal connectives (fig. 9). The point of insertion lies on the postero-ventral wall of the mandibular cavity and thus its function is that of a rotator.

The protraction-counter-rotation of the mandible is brought about by muscles 7, 8, 9, 10, 14, 15 and 16. Muscles 7 and 8 originate from the posterior tentorial apodeme immediately behind the mandibular boss and insert on the chitinous bulge on the dorsal inner wall of the mandibular cavity. The contraction of these muscles brings about protraction as well as counter-rotation of the mandible.

Mandibular muscles 9 and 10 originate from the median dorsal head wall (fig. 6) and insert on the dorsal chitinous bulge in the mandibular cavity. The contraction of these muscles causes rotation of mandible in a direction opposite that of muscles 1, 2, 3, 4, 5, 6 and 17. Muscle 13 is a broad muscle originating from the anterior tentorial apodeme (fig. 9) and inserted on the inner lateral wall of the mandibular cavity, dorsal to the point of insertion of muscles 15 and 16. The point of origin of muscle 13 is slightly anterior to the point of its insertion. Hence the contraction of this muscle may cause a very small protraction and also some abduction of the anterior end of the mandibles.

Mandibular muscle 14 originates ventrally from the anterior median point of the transverse mandibular tendon and is inserted on the lateral inner wall of the mandibular cavity on the same level and anterior to the point of insertion of muscle 13 (fig. 3). The origin of muscle 14 is slightly posterior and lower than its insertion, so that the contraction of this muscle will tend to adduct the anterior end of the mandible, but working in unision with muscles 15 and 16 it is used to counteract any excessive abduction effect produced by muscles 15 and 16. This interpretation of the action of muscle 14 disagrees with that of Manton (1964) who regards it as a levator. Mandibular muscles 15 and 16 (figs. 3 and 9) are inserted on the inner lateral wall of the mandibular cavity ventral to the point of insertion of muscle 13. These muscles alone would cause abduction of the anterior ends of the mandibles, but in combination with the other muscles of this group they probably have a stablizing function during the movement of the mandible.

Maxillae: The detailed structure of the maxilla head of *T. longicornis* is shown in fig. 4. The maxilla head is divisible into an inner ventral part, the lacinia, and an outer dorsal part, the galea. The lacinia is modified into three

fans—the inner fan, the ventral fan and the outer fan. The inner fan is fused at its base with a supporting retort-shaped structure, and similarly the ventral fan is fused with its supporting structure, the hyaline plate. The galea is modified dorso-laterally into a claw with these teeth. Mesially it gives rise to a hollow out growth bearing a large number of bristles, called the appendages of the galea. This is possibly used in moving food particles from the lingua into the cibarium. The dorso-mesial part of the galea is produced posteriorly into the cavity of the stipes and is referred to as the galeal extension. The lacinia is immovably fused together at their bases where they form a heavily chitinised ring which is movably articulated with the stipes. The articalation is such that the movement of the maxilla head is restricted to the lateral plane.

The framwork of the body of the maxilla is formed by the stipes. Anteriorly the stipes bears a palp (fig. 4). At the level at which the palp fuses with the stipes, it also fuses laterally with the postero-lateral margin of the hypopharynx. At this point the maxilla and hypopharynx together form the maxillary apodeme (fig. 8) which bears maxillary muscles I to IV. Sections in fig. 8 G to H would reveal that this apodeme is formed from the fusion of the dorsal wall of the stipes with the base of the palp and the posterolateral wall of the super-lingua, Sections taken in a more posterior region show that at the point of fusion of the ventro-mesial wall of the stipes with the lingua in the region marked with an asterik in fig. 8 F, a small chitinous pocket is left which is continuous with the preoral cavity. This is the maxillary apodeme and serves as the point of insertion of maxillary muscles I to IV (fig. 5).

The main movements of the maxillae in *T. longicornis* are those of protraction accompanied by abduction, and retraction associated with adduction. The maxilla can be protruded through the opening of the pre-oral cavity by maxillary muscles VIII, IX. Muscles VIII and IX originate from the transverse maxillary tendon and inserts on the cardo (fig 9 M). These muscles VIII, IX and XI cause protraction accompanied with some abduction of the maxillary head, while muscle which originates from the mid-ventral aspect of the transverse maxillary tendon, inserts on the cardo and is employed as an abductor of the maxilla head. Since the muscle joins with its fellow of opposite side and is loosely fastened to the transverse maxillary tendon by a thin connective tissue fibre, this may also act as a stabilizer (Manton 1964).

The retraction-adduction movement of the maxilla is brought about by muscles I, II, III, IV, V, VI, VII and XII. The point of origin of muscle I lies on the stipes, that of muscles II on the cardo and that of muscles III and IV on the posterior lateral wall of the head. Muscles I, II, III and IV insert on the maxillary apodeme. Muscle I and II are primarily adductors of the maxilla head, whilst III and IV are retractors. As a result of contraction of muscles I, II, III and IV, the maxilla head is also moved towards the median line, while the maxilla is retracted. Muscles V, VI and VII (fig. 5) originate from the posterior tentorial apodeme and insert on the inner lateral wall of the stipes. Muscle V functions as a retractor Muscle VI and VII act as adductors. Muscle XII originates from the median dorsal head region, anterior to the point of origin of the mandibular muscle 3 (fig. 6) and inserts on the dorsal inner wall of the cardo and functions as a retractor.

Hypopharynx. In Collembola, the hypopharynx is well developed and plays an important role in feeding. The general form and structure of the hypopharynx and the cuticular structure associated with it are illustrated in text figure 11.

The hypopharynx is modified according to the nature of the food. In contrast with fluid feeders in which the hypopharynx has a smooth surface devoid of cuticular processes and serving as floor of the food meatus, in *T. longicornis*, which feeds on solid food, the hypopharynx has a complete series of bristles and processes. It is modified for procuring solid and semi-solid food and conducting it back to the mouth. The free dorso-lateral part of the lingua and ventral aspect of superlingua bear three longitudinal tracks of bristles between which the fans of the maxilla head work (fig. 7 A). The longitudinal rows of bristles on the hypopharynx assist in conducting food to the mouth and also prevent the food particles from escaping into the lateral groove (fig. 7*c*). Posteriorly they are continued as transverse rows of bristles so that the food, brushed along the longitudinal and transverse rows of bristles on hypopharynx, comes to lie in a narrow space at the anterior end of the cibarium. The transverse rows of bristles appear to prevent the food from moving anteriorly, which function is also performed by the 4th and 5th transverse rows of bristles which are borne along the mid line on a raised area and are directed posteriorly. The latter are food retaining valve (fig. 5) The superlinguae bear on their dorsal surfaces, one longitudinal track of bristles which serve to prevent the food particles escaping dorso-laterally across the surface of the superlingua into the pre-oral cavity in the region of the mandibular diastema. The superlingue are lobed on their median surface forming two pairs of distinct pads. The function of the pads and the lobed margins of the superlinguae is possibly to prevent the food particles from escaping dorsally across the superlingue.

The posterior part of each superlingua is fused ventrally to the postero-dorsal surface of the lingua in such a way that the median dorsal surface of the lingua continues posteriorly as the floor of the food meatus or cibarium. The sides and the roof of the cibarium are formed by the arching of the toothed mesial edges of the superlinguae which assist in the food being picked up between the molar plates during rotation-retraction movement. The cibarium opens anteriorly opposite the oval space between the superlinguae while posteriorly this groove is raised and forms a triangular oral valve (fig. 6) which lies in front of the mouth. The base of the oral valve lies dorsally and is continuous posteriorly with the ventral wall of the oesophagus while the two sides are formed by the cibarium. It acts as a door, opening the passage to the mouth only when the mandible is rotating. The hypopharynx is devoid of any muscle of its own. The movement of the lingua and the superlinguae is brought about by the movement of the anterior and posterior tentorial apodemes.

Buccal cone, pre-oral cavity and oesophagus. The conical hypostome is bounded dorsally by the labrum and ventrally by the labium and encloses a space between them known as the pre-oral cavity. In repose, the mouth parts are concealed in the pre-oral cavity and the slit-like opening of the pre-oral cavity is tightly closed by the labrum and labium. (fig. 13*a*)

The labrum is an unpaired quadrate leaf-like structure, broader at the base than at the apex. Longitudinal sections show that the edge of the labrum, proximal to its attachment with the frontal sclerite, becomes slightly invaginated to form a sigmoid ridge of thick elastic cuticle, referred to as the fronto-labral suture. The fronto-labral suture provides sufficient elasticity to allow return of the labium to its original position during relaxation of the labral muscles. This mechanism explains the absence of elevator muscles in the labrum. This fronto-labial suture is at the base of the hypostome in *T. longicornis* (fig. 6). The dorsal surface of the labrum bears a number of suitable bristles believed to be sensory in nature. The distal margin of the lip of the labrum, the structure of which is

correlated with the feeding habit of the species in question, is semi-circular, stiff and provided with a large number of minute, backwardly directed bristles in this species feeding on solid moist food. It helps in conducting food particles into the pre-oral cavity (fig. 13).

A pair of labral muscles originates from the fronto-labral sutures and inserts on the distal end of the labrum (fig. 6). These muscles help to depress the labium. At its tip, the labrum continues backwards and inwards as the epipharynx (fig. 6 and 12) which forms the roof of the pre-oral cavity. The epipharynx can be divided into two regions—the anterior region bears the assymetrical saw-like and flap-like structures and the posterior region bears the lateral folds. The anterior region is wedge-shaped in transverse sections (fig. 16 A, B) so that when it meets the median dorsal part of the lingua, it divides the food meatus into two lateral channels. The wedge-shaped structure of the pharynx extends posteriorly to a point above the food retaining valve on the lingua. Posterior to this point, the epipharynx gradually becomes concave and bears lateral folds in the region where it lies dorsal to the madibular molar plate. Posteriorly, the epipharynx encloses the oral valve (fig. 16 D). The various chitinous structures borne by the epipharynx in *T. longicornis* are illustrated in fig. 12. These chitinous structures keep the food particles confined to the food meatus.

There are two pairs of epipharyngeal dilators (fig. 6). These insert on the epipharynx and originate from the fronto-lateral sutures and their contraction creates a negative pressure. The oesphageal muscles consist of the dorso-lateral oesophageal dilators which are divided into two groups—six pairs of anterior and four pairs of posterior dorso-lateral oesophageal dilators. The origin and insertion of these muscles and also the manner of their attachement are illustrated in text figures 6, 7 and 8. By contracting, these muscles pull up the roof of the oesopharynx whereas its floor is pulled down by another set of five pairs of muscles, the ventro-lateral oesophageal dilators. Thus these muscles can create a negative pressure in the oesophagus. The contraction of the oesophagus is brought about by constrictor muscles (fig. 6).

The structure of the labium is illustrated in the text figure 13 *b*, *c*. Subulate sensory bristles are found on the outer surface of the labium. The labial muscles in *T. longicornis* are stouter than in the fluid feeders (Singh 64*a*). There are six pairs of these, four pairs of elevators and two pairs of depressors. The labial musculature resembles that of *T. plumbeus*, described by Hoffmann (1908), whose sequence of numbering has, therefore, been adapted

The labial muscle 1 originates from the posterior tentorial apodeme and is inserted at the inner anterior end of the mentum through the intermediary of a ligament which is itself attached to the chitin by fibrils. Muscle 2 is formed by the union of two diverging branches a longer and thinner branch, originating from the posterior tentorium and a shorter and thicker branch originating near the point of insertion of muscle 6 of the postero-mesial end of the submentum. Both these diverging branches join at the level of the posterior margin of the submentum and insert on the antero-lateral angle of the mentum, mesial to muscle 3. The points of origin of muscles 3 and 4 lie on the posterior tentorial apodeme and their points of insertions on the lateral inner part of the mentum. Labial muscle 5 also takes its origin from the posterior tentorial apodeme but inserts on the median posterior end of the mentum. Labial muscle 6 which is the posterior most, strongest and shortest labial muscle also originates from the posterior tentorial apodeme and is inserted on the posterior side of the median chitinous thickenning. It is interesting to note that three of the muscles are inserted close

together while one *viz.* 1, is inserted mesially alone on the anterior angle of the labium. Possibly the effect produced by these muscles results in the formation of a concave inner labial surface for scooping. The contraction of muscles 5 and 6 will depress the labium and also restrict the protrusion of the anterior end of the posterior tentorial apodeme and, thereby, the hypopharynx. It also acts as a pivot for raising the anterior end of the hypopharynx. These muscles would move the labial palp dorso-ventrally, causing downward movement of the bristles of the palp.

Feeding machanism

An account can now be given of the method of feeding in *T. longicornis* on the basis of the detailed anatomy of the mouthparts and their musculature, movements of the mouthparts as observed in living animals and experiments to show the path followed by food.

T. longicornis feeds mainly on moist solid food particles but is also capable of feeding on fluid food materials (Singh, 1964*b*).

Whilst feeding on solid food, the hypostome is directed against the food and the mouthparts are then protruded through the opening of the pre-oral cavity, which is widened by lowering the labium and raising the labrum. During this process the tips of the mandibles and maxillae diverge, as they emerge from the opening of the pre-oral cavity, until they are fully separated on the food surface. At the same time, the hypopharynx is also slightly protruded. As soon as the mouthparts touch the food surface, the protraction, which is also accompanied by a counter-rotation movement of mandibles, stops and the various mouthparts take up their operative positions. The first incisor tooth of the mandible pierces the food and its length limits the depth of the scraping, while the remaining incisors, with their tips facing ventro-mesially, grip the food and are ready to scrape the surface during the rotation-retraction movement.

The maxilla heads, lying ventro-lateral to the mandible and the superlinguae, remain on the food with their inner fans facing ventro-mesially, the ventral fan lying laterally and the outer fan more dorsal in position. The hypopharynx and the labium are pressed against the food from beneath in the median line, whilst the labrum presses the food with its distal row of bristles from above. When this arrangement of the mouthparts on the food is completed at the end of protraction, a rotation-retraction movement starts. At the commencement of the rotation-retraction movement the incisors begin to move towards the median side and at the same time retract into the pre-oral cavity, cutting and scraping the soft food (fungal hyphae and spores) as they do so. The mandibles are brought closer together as they move backward, and with them a portion of the food which they scrape may also be moved in the median line and is brought on the tip of the lingua lying below and near the food. Following the retraction of the mandibles, the maxillae begin to move mesially and backward, sweeping the rest of the food on to the tip of the lingua with the help of the fans. During this movement, the maxilla head is slightly rotated so that the outer fan now comes to lie laterally before entering the pre-oral cavity. The function of the outer fan is to prevent stray fungal elements entering the opening of the pre-oral cavity laterally.

As the maxilla head is in the process of retraction, the hypopharynx and the labium are pressed against the food and also raised in order to scoop the food brought between and in front of them by the mandibles and maxillae. The distal backwardly directed bristles on the tip of the labrum are lowered and pressed as the mouthparts and hypopharynx with the food between them are retracted backward into the pre-oral cavity.

In this way the food materials which have been cut and scraped by the mandibles are brought inside the pre-oral cavity with the help of the hypopharynx, mandibles and maxillae, all working slightly out of phase with each other. When the mandible, maxillae and hypopharynx are sufficiently retracted inside the pre-oral cavity, the external opening is closed by the approximation of the labium and labrum. As a result of the lowering of the labrum, the wedge-shaped anterior portion of the epipharynx hangs vertically downward above the lingua so that the food meatus at this end is divided longitudinally into two lateral halves. In each half of the food meatus the maxilla head rushes the food backward in the pre-oral cavity. The food now lies along the dorso-lateral sides of the wedge-shaped lingua between the maxilla heads and superlinguae and below the epipharynx. In the pre-oral cavity the retraction of the hypopharynx ceases but that of the maxillae and mandibles continues for some distance. The fans of the maxillae lie between the lingua and superlinguae in such a way that the free part of their bristles work in close association with the rows of bristles on the lingua and superlinguae. After the movement of the hypopharynx has ceased, and while the maxillae continue to retract, the free margins of the inner and ventral fans sweep the food particles along the longitudinal rows of bristles on the lingua and superlinguae, and deposit them at the posterior end of the lingua.

During the passage of the food from the distal end of the lingua to the posterior end, the anterior and posterior pads, and a median ridge of the epipharynx also prevent the food from escaping dorsally between the superlingua and epipharynx. The food deposited at the posterior end of the lingua is pushed back into the cibarium by the galeal appendages of the maxillae (figs. 4 and 6). The food which has been pushed into the anterior end of the cibarium remains on the floor of the cibarium during the subsequent protraction movement of the mandibles and maxillae but when retraction and rotation of the mandibles commences once more, it is picked up between the rotating medibular molar plates, as they pass the rows of superlingual teeth. All the food particles above the cibarium are thus taken up between the rotating mandibles which, in so doing, also comminute them. During the rotation movement, the epipharynx is applied dorsally to the molar plate so that the anteriorly directed bristles of the crescentric flap prevent any ground up food escaping antero-dorsally.

As the rotation continues, the mandibular hook (fig. 2) pushes the lateral folds apart so that a narrow gap remains between them and the oral valve. The food particles are sucked in through the opening between the lateral folds and the oral valve into the oesophagus. The food from the oesophagus is forced into the gut by the contraction of the constrictor muscles.

Although the usual food of *T. longicornis* is of a solid or semisolid nature, it can also feed on fluid food. The hypopharynx is greatly modified for feeding on solid food particles but it can also be employed in fluid feeding. A functional watertight sucking tube is formed in the pre-oral cavity by sealing the sides of the food meatus (fig. 14*B*). The roof of this tube is formed by the epipharynx and the floor by the lingua. The outer edges of the superlinguae are pressed against the epipharynx and the inner edges are in contact with the body of the lingua. During fluid feeding, the superlinguae are at an angle to their usual position. This is brought about by pressure from beneath, exerted by the maxillae heads. In this way a rather sort of tube is formed which, however, is sufficiently watertight to allow fluid feeding.

In the region of the mandibular molarplate the lateral edges of the superlinguae are raised by the maxilla. The superlinguae are pressed against the

mandibles and thus seal the space between them. The lateral folds of the epipharynx prevent the escape of fluid dorso-laterally above the molar plates and in this way seal the space between the epipharynx and the mandibles and open the passage between the lateral folds and the oral valve. The tip of the water-tight tube is formed by hypopharynx below and the labrum above. This is dipped into the food and the fluid is sucked into the pre-oral cavity by the negative pressure created by the action of the epipharyngeal and oesophageal dilator muscles. The mandibles and maxillae remain immobile during fluid feeding.

Summary

The detailed anatomy and arrangement of the mouthparts of *T. longicornis* has been described. The mouthparts are of the biting and scraping type, with well developed mandibular molar plates and complex maxillary heads. Arrangements of mandibular and maxillary muscles are similar to those described by Hoffmann (1905 and 1908) and Manton (1964). The structure of the hypopharynx and the hitherto unknown tongue-like oral valve has been fully described and their relationship with feeding mechanism discussed. The complex epipharynx is wedge-shaped anteriorly where it divides the food meatus into two lateral channels while posteriorly it forms the arched roof of the food meatus. Solid food particles are swept along the lateral channels between the lingua and superlinguae by the fans of the maxillary heads and finally deposited before the entrance of the cibarium. After further protraction movement, food is picked up from the floor of the cibarium by the mandibular molar plates which grind and carry it dorsally to the opening of the mouth, from where it is sucked into the oesophagus through the oral valve due to the negative pressure created inside the oesophagus. For feeding on fluid food, a functional tube is formed between the lingua, superlinguae, and epipharynx. Through this improvised functional tube, fluid food is sucked into the oesophagus by the negative pressure created by the oesophageal dilator muscles.

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Growth of two common weed species under different intensities of competition from wheat and gram[1]

By

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Introduction

Weeds are the plant species growing where they are not desired. By competing with our crop plants far various growth requirements such as water, light, mineral nutrients and carbon dioxide of the air, they exert considerable influence over the crop growth and as a consequence the yield is reduced. However, the weeds do not remain unaffected and their growth also suffers on account of competition from crop plants. It has already been reported that with increase in crop density, weed growth is suppressed (Tripathi, 1967), Besides crop density, the time of emergence of weeds and crops also contributes much to the relative success of individuals involved in competition. In the present paper, the results of the experiment conducted to study the effects of different intensities of competition from wheat and gram on the growth of two common weed species, have been reported.

Experimental Procedure

Different intensities of competition were created by changing the sowing period of crops and the weeds. The weeds under consideration are *Asphodelus tenuifolius* Cav. and *Euphorbia dracunculoides* Lamk., and the crops are wheat (*Triticum aestivum* L.) and gram (*Cicer arietinum* L.). The crop and the weed plants were grown in earthenware pots of uniform size filled with arable soil and the following treatments were given.

1. *A. tenuifolius* grown in already established (20 days old) crop plants.
2. Plants of *A. tenuifolius* and those of the crops grown at the same time.
3. *A. tenuifolius* already established (20 days old)—crop plants grown 20 days later. Thus, in the initial growth stage (upto 20 days) no competition was offered by the crop plants.
4. *A. tenuifolius* grown alone—no competition offered by the crop plants.

In the first three treatments, each pot contained 10 plants, 5 each of crop and weed. The pots of "no-competition" set differed from others in containing 5 weed plants and no crop plant. For each treatment, 3 pots were maintained. The treatments were given in such a way that the age of the weed plants remained same in all the cases.

Commencing from the second week of December, 1963, the experiment continued upto second week of March, 1964 when the dry weight of shoot and root of *A. tenuifolius* was determined.

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An experiment similar to that described for *A. tenuifolius* was also performed with *E. dracunculoides* and the dry weight of shoot and root of the weed under different intensities of competition from wheat and gram was taken. The duration of the experiment was only 2 months in this case.

Results

Data are summarized in tables 1 and 2. Dry weight of shoot and root of *A. tenuifolius* is the highest when there is no competition with the crop plants while the lowest values are obtained in treatment no. 1 where the weed plants were grown in the pots with already established crop plants. In treatment no. 2 also the competition offered by the crop is quite effective in bringing down the shoot and root growth of the weed (Table 1).

TABLE 1

*Effect of different intensities of competition from wheat and gram on shoot and root *dry weight of Asphodelus tenuifolius* Cav.

Treatments	Competition from wheat		Competition from gram	
	Dry weight shoot (g)	Dry weight root (g)	Dry weight shoot (g)	Dry weight root (g)
1	0·97 ±0·21	0·11 ±0·03	0 91 ±0·02	0.16 ±0·05
2	1·45 ±0·22	0·15 ±0·07	1·62 ±0·19	0·18 ±0·03
3	2·97 ±0·27	0·25 ±0·11	3·24 ±0·31	0·31 ±0·06
4	3·62 ±0·12	0·40 ±0·08	3·62 ±0·12	0·40 ±0·08

*Values per 5 plants, obtained by taking average of 3 replicates.

TABLE 2

*Effect of different intensities of competition from u heat and gram on shoot and root *dry weight of Euphorbia dracunculoides* Lamk.

Treatments	Competition from wheat		Competition from gram	
	Dry weight shoot (g)	Dry weight root (g)	Dry weight shoot (g)	Dry weight root (g)
1	0·64 0·15	0·15 ±0·04	0·56 ±0·08	0·18 ±0·04
2	0·82 ±0·15	0·18 ±0·37	0·80 ±0·13	0·20 ±0·05
3	1·32 ±0·4	0·27 ±0·14	1·08 ±0·13	0·30 ±0·02
4	1·74 ±0·29	0·38 ±0·08	1·74 ±0·29	0·38 ±0·08

*Values per 5 plants, obtained by taking average of 3 replicates.

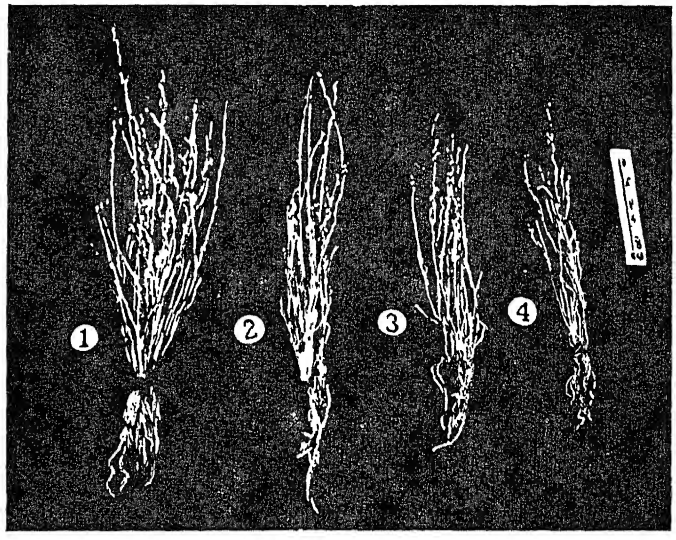

Fig. 1. Effect of different intensities of competition from wheat plants on *Asphodelus tenuifolius* Cav.

1. *A. tenuifolius* grown in the pots without any competition from wheat plants.
2. *A. tenuifolius* plants already established-crop grown in the pot 20 days later.
3. *A. tenuifolivs* and crop grown at the same time.
4. *A. tenuifolius* grown with already established crop plants. (Scale in figure measures 10 cm).

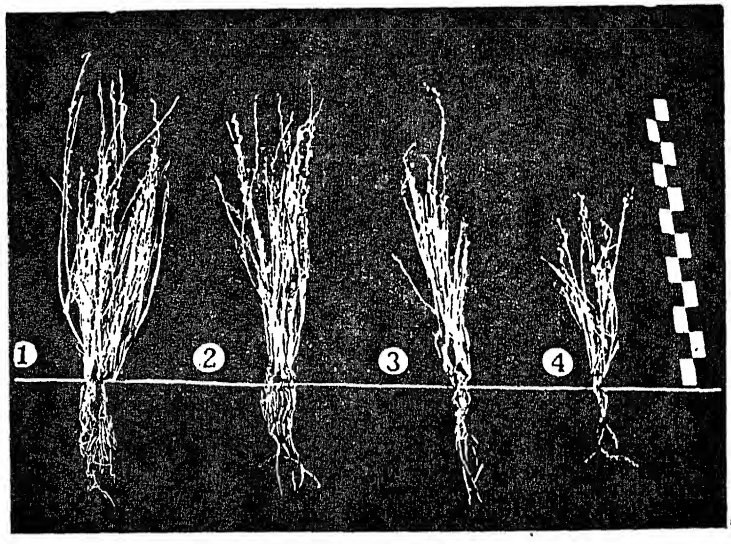

Fig. 2. Effect of different intensities of competition from gram plants on *A. tenuifolius* Cav. Treatments 1, 2, 3, and 4 are same as in figure 1. Scale in figure measures 30 cm.

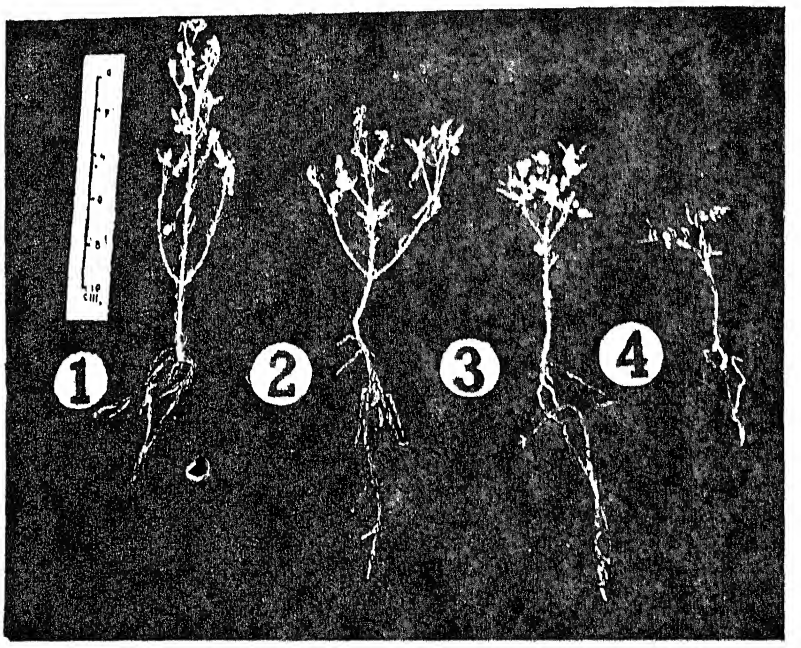

Fig. 3. Effect of different intensities of competition from wheat plants on *Euphorbia dracunculoides* Lamk.

1. *E. dracunculoides* grown in the pot without any competition from crop plant.
2. *E. dracunculoides* plants already established-crop plants grown in the pot 20 days later.
3. *E. dracunculoides* and crop grown at the same time.
4. *E. dracunculoides* grown with already established crop plants (Scale in figure measures 10 cm.)

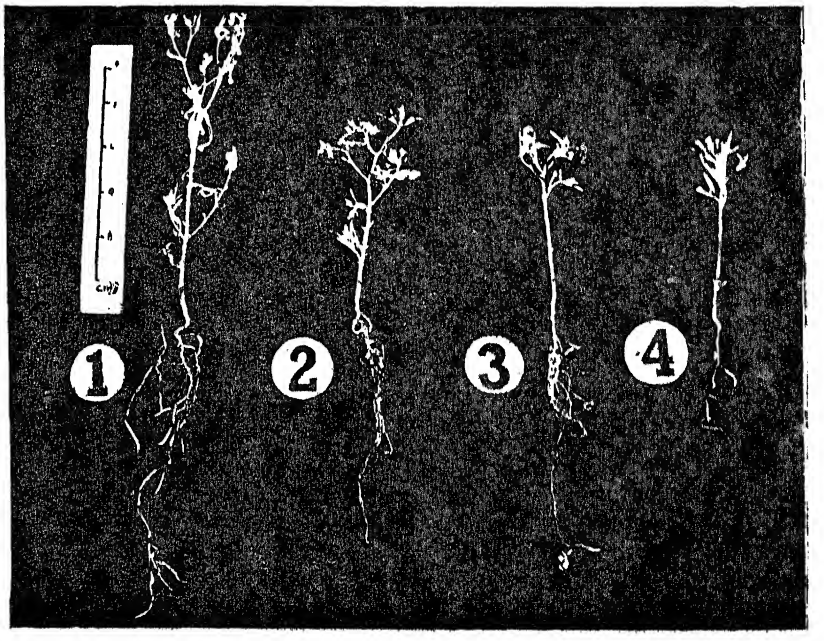

Fig. 4. Effect of different intensities of competition from gram plants on *Euphorbia dracunculoides* Lamk.

Treatments 1, 2, 3 and 4 are same as in figure 3. (Scale in figures measures 10 cm.)

In treatment 3 where the crop plants were grown in the pot 20 days after weed emergence, the growth of the weed was not much affected.

It is evident that the growth of the species establishing first remains less affected by the competitors emerging later while late emerging competitors at the same time show suppressed growth on account of intense competition offered by the established plants (Table 1).

A comparison of the competitive effects of wheat and gram over *A. tenuifolius* suggests that wheat competes with this weed better than gram (compare figures 1 and 2), though in treatment no. 1 shoot growth of the weed appears to be better when grown with gram.

A gradual increase in shoot and root dry weight of *A. tenuifolius* from treatment no. 1, to treatment no. 3, indicates that the intensity of competition offered by the crop plants deteriorates as the sowing period of the crop is delayed.

Data summarized in table 2 indicate that the dry weight of shoot and root of *E. dracunculoides* goes on increasing from treatment no. 1 to 4. Competition remains most severe in treatment no. 1 where the weed plants grow with already established wheat and gram plants. Data also suggest that the shoot growth is more severely affected by gram (compare figures 3 and 4), while wheat is more successful in reducing the root dry weight under varying competition intensities.

Discussion

The intensity of competition offered by the crop plants to weeds increases with the delay in emergence of the latter, as is clear from dry weight estimation of *A. tenuifolius* and *E. dracunculoides* growth under different intensities of competition from wheat and gram (Tables 1 and 2) and figures 1-4. Thus, the individuals establishing first get the upper hand and offer intense competition specially for light, to the plants emerging later, which in the long run show much suppressed growth. Such an effect due to competition for light by overlapping of leaves of closely spaced sunflower plants has also been shown by Clements *et al.* (1929). Similarly, reproductive structures of *Allium viniale* put in an established Sward (*Lolium* sp.) have been observed by Lazenby (1961) to show reduced growth rate and to give rise to fewer plants than those planted with or before *Lolium*. The findings of the experiment suggest that such weed seedlings as appear in the cultivated fields before or simultaneously with the crop seedlings should be removed from the fields as soon as possible. This will prove quite helpful in minimizing the harmful effects of weeds, as the weeds coming up in the fields later are considerably susceptible to the intensity of competition that the crops like wheat and gram offer.

As indicated by the comparative effect of wheat and gram over weeds, wheat offers more severe competition to *A. tenuifolius* and gram appears to be more successful in reducing the shoot growth of *E. dracunculoides*. Root growth of the latter, however, differs in its response. Other studies on weed-crop-interaction (Tripathi, 1965) indicate that gram competes more severely with *E. dracunculoides*. Possibly, the similarity in form of wheat with *A. tenuifolius* and of gram with *E. dracunculoides* is responsible for the severe competition effects between these. Clements *et al.* (1929) and Weaver and Clements (1938) have also stressed that the degree of competition largely depends upon the similarity in forms.

Summary

The paper embodies the results of the experiments on weed-crop-interaction under controlled conditions. Two common weed species, *Asphodelus tenuifolius* Cav. and *Euphorbia dracunculoides* Lamk., were grown under different intensities of competition from the plants of wheat and gram crops and their shoot and root growth as indicated by the dry matter production was noted. It has been found that the weed plants grown in already established crop show sufficiently poor growth, while the crop plants grown in the pots where the weeds were already established, could offer only slight competition to weeds. Wheat is more successful in reducing the shoot growth of *A. tenuifolius* while shoot growth of *E. dracunculoides* is more reduced by gram.

Acknowledgement

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Utilization of Amino Acids in mixture by four isolates of *Botryodiplodia theobromae*[1]

By

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Numerous workers including Leonian and Lilly (1938), Steinberg (1942), Pyle (1954), Skoropad and Arny (1957), Thind and Randhawa (1957), Tandon and Chandra (1961), Bhargava (1962), Loprieno and Guglielminetti (1962), Kurtz and Fergus (1964), Lopez and Fergus (1965) and Prasad (1965) have investigated the role of individual amino acids in the nutrition of fungi. They concluded that all the amino acids are not of equal value in fungal nutrition. Leonian and Lilly (1938), while working with 24 amino acids, on 14 fungi, observed that no single amino acid was best for all the species. Steinberg (1942) found that out of 22 amino acids only 7 were satisfactory for the growth of *Aspergillus niger*. Lilly and Barnett (1951) have reported that fungi may or may not utilize a mixture of amino acids more favourably than any individual one. It has been conclusively proved that the effect of one amino acid on the utilization of another depends on the particular amino acids as well as the organism involved.

The present investigation was, therefore, undertaken to study the effect of glycine, glutamic acid, asparagine and aspartic acid, individually, on the utilization of some amino acids which usually exist in many of the hosts in mixed condition.

Materials and Methods

Four isolates of *Botryodiplodia theobromae* Pat., obtained from rotten fruits of citrus, guava, mango and sapodilla, were employed. The mixture of amino acids consisted of four amino acids. Three amino acids in each mixture were kept common, the fourth was varied in each case. The constituent amino acids in each mixture were as follows :

Mixture 1 : L–leucine + DL–valine + DL–α–alanine + glycine.

Mixture 2 : L–leucine + DL–valine + DL–α–alanine + L(+) glutamic acid.

Mixture 3 : L–leucine + DL–valine + DL–α–alanine + L–asparagine.

Mixture 4 : L–leucine + DL–valine + DL–α–alanine + DL–aspartic acid.

The total amount of nitrogen in each mixture was similar to that present in 3·5 g. of KNO_3. The influence of the amino acids on the utilization of glucose was also studied. The basal medium consisted of 10 g of glucose, 1·75 g of KH_2PO_4, 0·75 g of Mg SO_4. $7H_2O$ and 1 litre of water. To this different

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TABLE 1

Showing the presence of amino acids, glucose (in days), drift in pH of the medium and average dry weight of different isolates of Botryodiplodia theobromae *on mixture* 1

	DAYS OF INCUBATION														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Citrus isolate															
Leucine	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
Valine	+	+	+	+	+	+	+	+	+		-	-	-	-	-
Alanine	+	+	+	+	+	+	+	+	+		-	-	-	-	-
Glycine	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Glucose	+	+	+	+	+	+	+	-	-		-	-	-	-	-
Drift in pH	6·0	6·0	5·8	5·5	5·5	7·0	7·3	7·6	7·6	8·0	8·2	8·2	8·2	8·4	8·4
Dry wt. in mg.					91·0					134·6				129·6	
Guava isolate															
Leucine	+	+	+	+	+	+	+	+					-	-	-
Valine	+	+	+	+	+	+	+	+	+	-	-		-	-	-
Alanine	+	+	+	+	+	+	+	+	-		-	-	-	-	-
Glycine	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Glucose	+	+	+	+	+	+	-	-	-	-	-	-	-	-	-
Drift in pH	6·0	5·8	5·6	6·0	6·1	7·1	7·3	7·6	8·0	8·2	8·2	8·2	8·3	8·5	8·5
Dry wt. in mg.					71·0					150·0				141·0	
Mango isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	-	-	-
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glycine	+	+	+	+	+	+	+	+	+	-	-	-	-	-	-
Glucose	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Drift in pH	6·0	6·0	5·8	5·5	6·1	6·4	7·0	7·1	7·3	7·3	7·5	7·5	8·0	8·2	8·2
Dry wt. in mg.					84·0					122·0				152·6	
Sapodilla isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glycine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	+	+	-	-	-	-
Drift in pH	6·0	5·7	5·5	6·3	6·6	6·6	6·9	6·9	6·9	7·0	7·0	7·3	7·3	7·6	7·6
Dry wt. in mg.					93·0					120·4				154·6	

TABLE 2

Showing the presence of amino acids, glucose (in days), drift in pH of the medium and average dry weight of different isolates of Botryodiplodia theobromae *on mixture* 2

	DAYS OF INCUBATION														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Citrus isolate															
Leucine	+	+	+	+	+	+	−	−	−	−	−	−	−	−	−
Valine	+	+	+	+	+	+	+	−	-	−	−	−	−	-	-
Alanine	+	++	+	+	+	+	+	−	−	−	−	−	−	−	−
Glutamic acid	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−
Glucose	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−
Draft in pH	6·0	5·8	5·7	6·6	7·0	7·3	7·3	7·6	7·6	8·0	8·2	8·2	8·2	8·2	8·2
Dry wt. in mg.					61·8					90·0					137·5
Guava isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Glutamic acid	+	+	+	+	+	+	+	−	−	−	−	−	−	−	−
Glucose	+	+	+	+	+	+	+	−	−	-	−	−	−	−	−
Drift in pH	6·0	5·8	5·6	6·0	6·4	6·4	6·6	6·9	7·3	7·6	7·6	7·6	7·9	7·9	7·9
Dry wt. in mg					110·0					148·6					179·0
Mango isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	−	−	−	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Glutamic acid	+	+	+	+	+	+	+	−	−	−	-	−	−	−	−
Glucose	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−
Draft in pH	6·0	5·8	5·5	6·3	6·7	6·7	7·0	7·3	7·3	7·6	7·6	7·8	7·9	8·2	8·2
Dry wt. in mg					83·3					133·0					161·0
Sapodilla isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glutamic acid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	−	−	−	−	−	−
Drift in pH	6·0	6·0	5·7	6·0	6·4	6·4	6·7	6·7	7·0	7·3	7·3	7·6	8·0	8·2	8·2
Dry wt. in mg					85·0					121·0					165·3

TABLE 3

Showing the presence of amino acids, glucose (in days), drift in pH of the medium and average dry weight of different isolates of Botryodiplodia theobromae *on mixture 3*

	DAYS OF INCUBATION														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Citrus isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Asparagine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	−	−	−	−	−	−
Drift in pH	6·0	6·0	5·6	6·0	6·3	6·3	6·3	6·4	6·6	6·6	6·6	6·6	6·8	7·0	7·0
Dry wt. in mg					64·0					85·8					121·6
Guava isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Asparagine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	−	−	−	−	−	−	−
Drift in pH	6·0	5·8	5·6	6·0	6·2	6·2	6·2	6·4	6·4	6·6	6·6	6·7	6·7	6·9	6·9
Dry wt. in mg					51·8					79·0					125·4
Mango isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	−	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Asparagine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	+		−	−	−	−
Drift in pH	6·0	6·0	5·7	6·0	6·3	6·3	6·3	6·5	6·6	6·6	6·6	6·8	6·8	7·0	7·0
Dry wt. in mg					43·6				76·0						139·3
Sapodilla isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Asparagine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	−	−	−	−	−	−
Drift in pH	6·0	5·7	5·5	6·0	6·3	6·3	6·4	6·4	6·6	6·6	6·8	6·8	7·0	7·0	7·0
Dry wt. in mg					68·4					95·3					129·6

TABLE 4

Showing the presence of amino acids, glucose (in days), drift in pH of the medium and average dry weight of different isolates of Botryodiplodia theobromae *on mixture* 4

	DAYS OF INCUBATION														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Citrus isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Aspartic acid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−
Drift in pH	6·0	5·7	5·5	6·0	6·2	6·2	6·2	6·4	6·4	6·4	6·5	6·5	6·7	6·7	6·7
Dry wt. in mg.					63·3					98·3				133·0	
Guava isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	−	−	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Aspartic acid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	−	−	−	−	−	−
Drift in pH	6·0	5·8	5·5	6·0	6·3	6·3	6·6	6·6	6·7	6·7	6·9	6·9	6·9	7·0	7·0
Dry wt. in mg					74·5					103·6				154·0	
Mango isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	−
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	−	−
Aspartic acid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−
Draft in pH	6·0	5·9	5·7	6·0	6·2	6·2	6·2	6·4	6·4	6·4	6·6	6·6	6·8	6·8	6·8
Dry wt. in mg					63·0					102·0				143·6	
Sapodilla isolate															
Leucine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Valine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Alanine	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Aspartic acid	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
Glucose	+	+	+	+	+	+	+	+	+	+	−	−	−	−	−
Draft in pH	6·0	5·7	5·5	6·0	6·2	6·2	6·3	6·3	6·3	6·5	6·5	6·5	6·7	6·7	6·7
Dry wt. in mg					68·0					97·0				131·0	

mixtures were added singly. Analytical reagents supplied by BDH or E. Merck were used during the investigation. 25 ml of the medium contained in 150 ml. Pyrex Erlenmeyer flasks were fractionally sterilized for three consecutive days for half an hour and then inoculated in triplicate with different isolates and incubated at 25±1°C for 15 days. Daily analysis of the medium for amino acids and glucose was made with the help of circular paper chromatographic techniques. Duplicate sets of chromatograms were run for amino acids and glucose both. Running solvent in both the cases was *n*–butanol : acetic acid : water (4 : 1 : 5, v/v). Diphenyl amine phosphate reagent was used as test reagent for sugar, whereas 0·1% ninhydrin for amino acids. pH drift was recorded daily with the aid of BDH narrow range pH indicator papers. The dry weight of the fungal mat was recorded after 5,10 and 15 days of incubation.

Results and Discussions

The results with regard to the utilization of amino acids, dry weight at different interval of incubation period, drift in pH and presence of glucose are recorded in Tables 1–4.

In general, it is evident from Tables 1–4 that mango and sapodilla isolates attained better growth on a mixture of amino acids than on a similar concentration of a single amino acid. Similar results have also been observed by Leonian and Lilly (1940), Robbins and Ma (1945) Beckman *et al.* (1953), Ram Dayal (1959) and Agnihotri (1962). On the other hand citrus and guava isolates exhibited different behaviour. Their growth on certain amino acids was better than on a mixture of amino acids.

It was further noticed that mixture 2 supported the maximum growth of all the isolates. In case of citrus and guava isolates it was followed by mixture 4, 1 and 3 and in mango and sapodilla isolates it was followed by mixture 1, 4 and 3. It is also interesting to note that although the mycelial yield of citrus and guava isolates was slightly better on aspartic acid than on glutamic acid but the reverse was true in the mixture where the growth was better in the medium where glutamic acid was present. Similar instance is also evident in mango isolate. Its growth was slightly better on asparagine than on glutamic acid, even though the mixture containing glutamic acid favoured better growth than that containing asparagine. Thus it can be seen that the growth response of an organism on a particular amino acid may or may not be equal when it is supplied singly or in combination with others.

Mostly the dry weight of the isolates increased upto the end of the incubation period except in citrus and guava isolates where it declined after 10 days on mixture 1.

The effect of a single amino acid *viz.* glycine, glutamic acid, asparagine and aspartic acid on the utilization of three amino acids (Leucine, valine and alanine, common in all the four mixtures) was very well marked in case of citrus and guava isolates. However, it was less pronounced in case of mango isolate. This effect was not evident in case of sapodilla isolate. It differed from the other three isolates as it was very slow in utilizing the various amino acids and many of them could not be consumed within 15 days. In all the four isolates the influence of asparagine and aspartic acid on the rate of assimilation of different amino acids was almost similar and this might be due to the former being the amide of the latter.

The data would also reveal that except in mango isolate the rate of utilization of glucose was significantly modified in different mixtures. It can be concluded that particular amino acid(s) influence the consumption of glucose.

It is generally considered that utilization of amino acid is preceded by deamination. According to Lilly and Barnett (1951), NH_3 released in the form of nitrogen during the process of deamination is assimilated by most of the fungi. Saksena *et al.* (1952) have also reported the accumulation of ammonia in some media containing amino acids. In the present investigation all the isolates lowered the pH of the medium at an early stage of their growth but subsequently it increased and shifted towards alkaline side. Similar observations have also been made by Raizada (1957), Saksena and Kumar (1961), Agnihotri (1962), Bhargava (1962) and Kakkar (1964). In the present study it was probably due to the early utilization of ammonia, which resulted in the decline in the pH of the medium, but it eventually increased due to the accumulation of excess of ammonia.

Summary

Effect of glycine, glutamic acid, asparagine and aspartic acid was studied singly on the rate of utilization of leucine, valine and alanine in mixture, by circular paper chromatographic technique. Mango and sapodilla isolates attained better growth on a mixture of amino acids than on a similar concentration of a single amino acid. Mixture No. 2 (L-leucine+DL valine+DL-α- alanine+L(+) glutamic acid) supported the optimum growth of all the isolates. The dry weight of the isolates increased upto the end of incubation period except in citrus and guava isolates where it decreased after 10 days on mixture 1. When glycine, glutamic acid, asparagine or aspartic acid were added singly in mixture of leucine, valine and alanine, exerted a marked effect on the utilization of three amino acids, in case of citrus and guava isolates, though it was less marked in mango isolate. In case of sapodilla isolate this effect was not at all evident. The pH of the medium was lowered by all the isolates during early stages of growth but later increased and shifted towards alkaline side.

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Proc. Nat. Acad. Sci., India, 39(B), I & II, 1969

Aspergilli From India I

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Out of 132 species of *Aspergilli* now recognised by Raper and Fennell (1965), nearly 44 only have yet been reported from India of which two new species were added from this laboratory (Mehrotra and Agnihotri, 1962). A concerted attempt is being made here to search for more Indian Aspergilli still unknown to us. The present paper deals with the six of the new finds. One of the species, *viz.*, *Aspergillus viridi-nutans* Ducker and Thrower is being reported here for the first time since it was described by its authors (Ducker and Thrower, 1954). The species are being described here in detail giving also the interesting features of the Indian strains.

Aspergillus clavato-nanica Batista, Maia, and Alecrim, in Anais fac. med. univ. Recife **15** (2) : 197–203 (1955).

Colonies on Czapek's solution agar growing well at 25°C (± 1°C), attaining a diameter of 3–4 cms. in 7–10 days, at first grayish blue green then lavender gray to endive blue (R., Plates XLVIII, XLIII), reverse light olive gray to mouse gray (R., Plate LI). Conidial heads crowded, 120–300 by 100–160μ; conidiophores either submerged or developing from aerial hyphae, hyaline, smooth, dilating upwards into a clavate vesicle, when submerged, mostly 225–495 by 7·5–15μ; when aerial, mostly 75–210 by 3·0–7·5μ; vesicles, hyaline, clavate, 15–60 by 10–25·5μ, mostly 30–50 by 15–21μ in submerged, and less clavate in aerially borne heads, 6–18 by 4·5–10·5μ, mostly 9–13·5 by 6–9μ; sterigmata in single series, more or less bottle shaped, 3·0–6·8 by 2·2–3·0μ, mostly 4·5–6·0 by 3·0μ; conidia subglobose to ellipsoid, smooth, light grayish green, 3·5–5·0 by 2·2–3·3μ, mostly 3·8–4·2 by 3–3·3μ when ellipsoid and 2·7–3·8μ in diameter when subglobose.

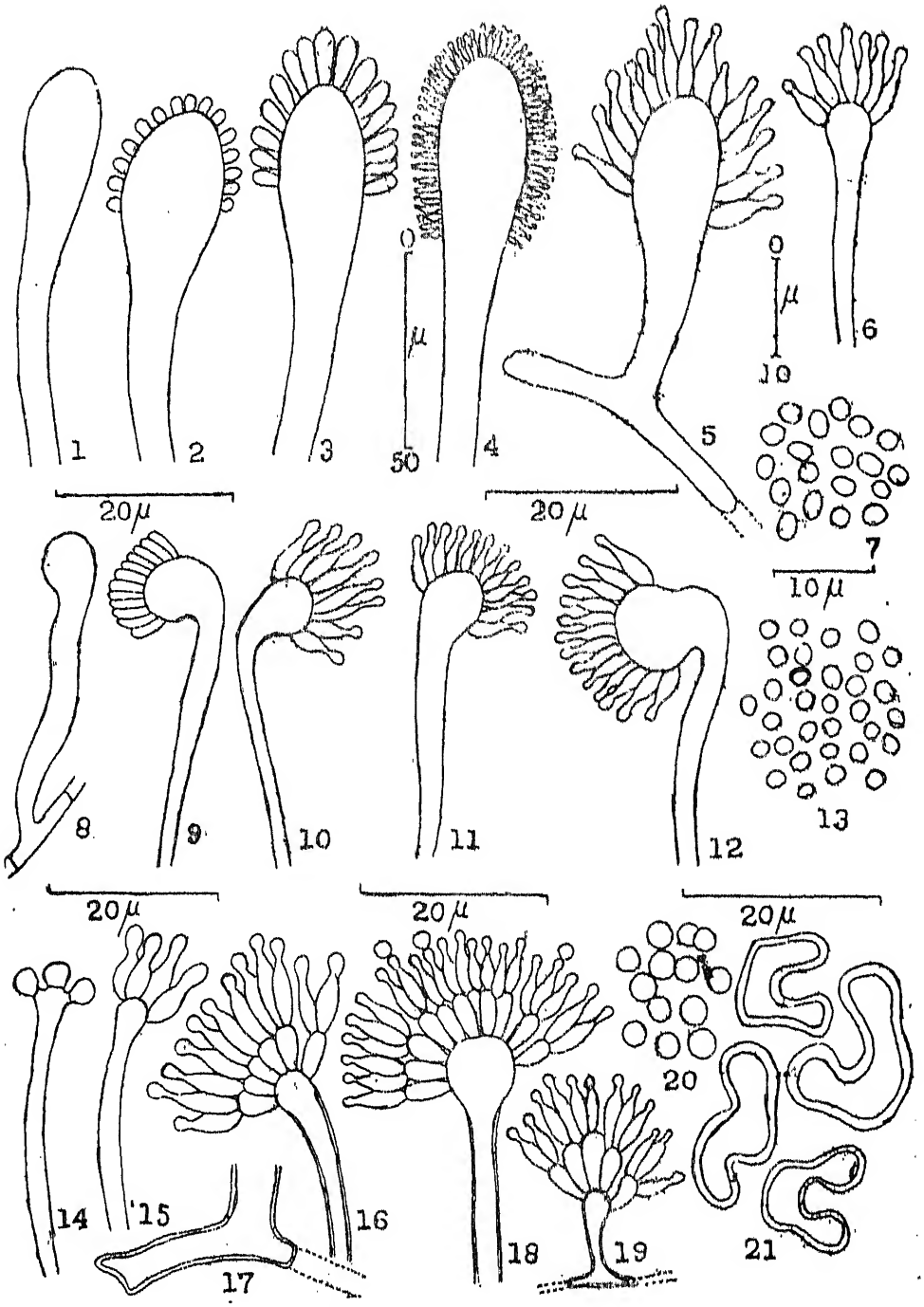
Colonies on malt extract agar ash green, somewhat more floccose 3–5·5 cms. in diameter in 7–10 days at 25°C (± 1°C), reverse deep olive buff (R., Plate XL) to pale smoke gray (R., Plate XLVI), other characters almost duplicating as on Czapek's agar except that the aerially borne heads often dominate the ordinary ones.

Description based on culture No. Ax-41, isolated from farm soil, pH 6·8, of Bhagwanpur (Bihar). Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate resembles much with the type description given by Batista, Maia and Alecrim. However, the conidiophores, sterigmata and conidia are almost similar on both Czapek's and malt agar media as observed by Raper and Fennell.

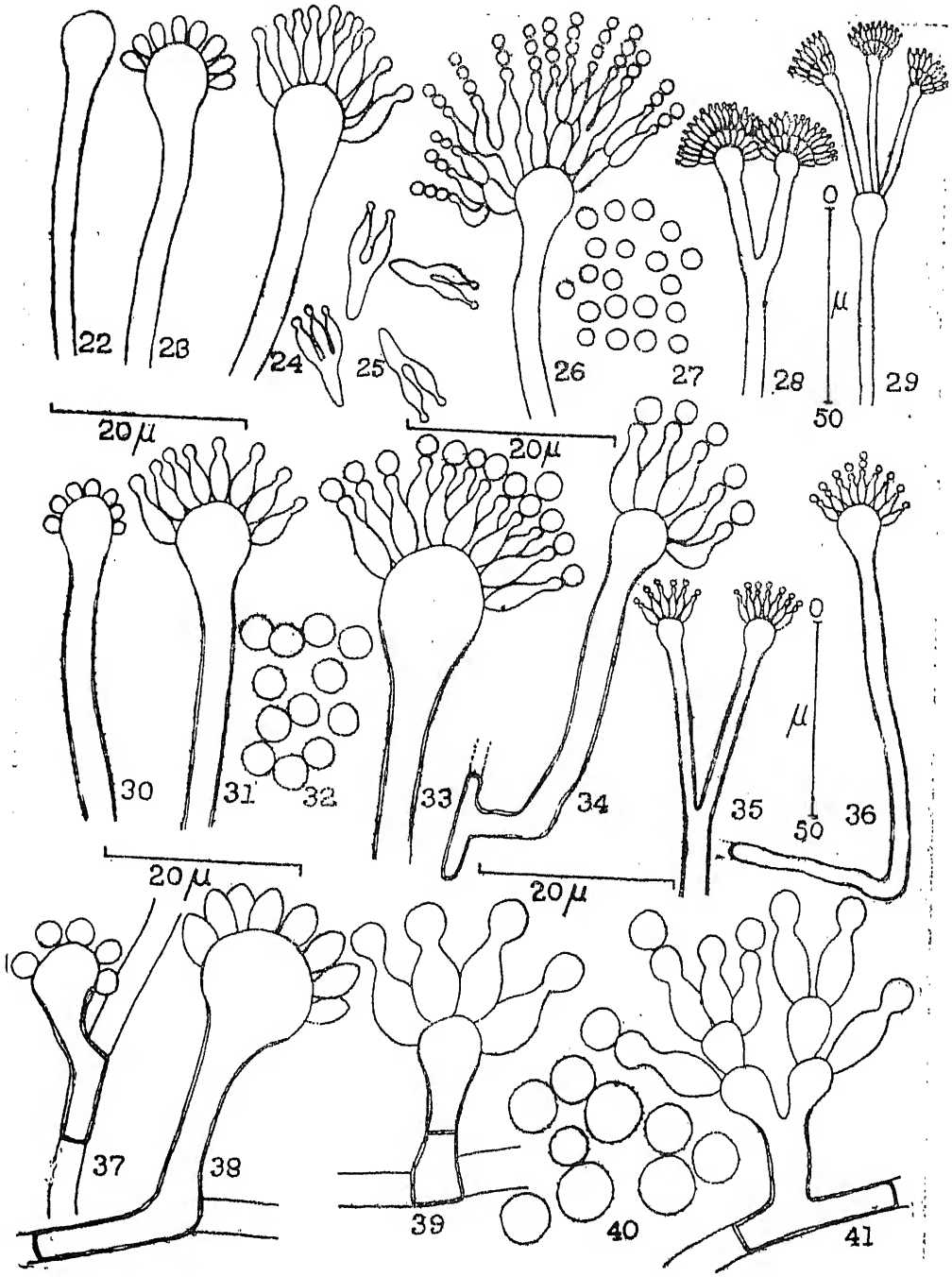
Aspergillus viridi-nutans Ducker and Thrower, in Australian J. Botany **2** : 355-364, Fig. 2 (1954).

Colonies on Czapek's solution agar growing fairly rapid at 25°C (± 1°C), attaining a diameter of 4–5 cms. in 7–10 days, at first white cottony with central



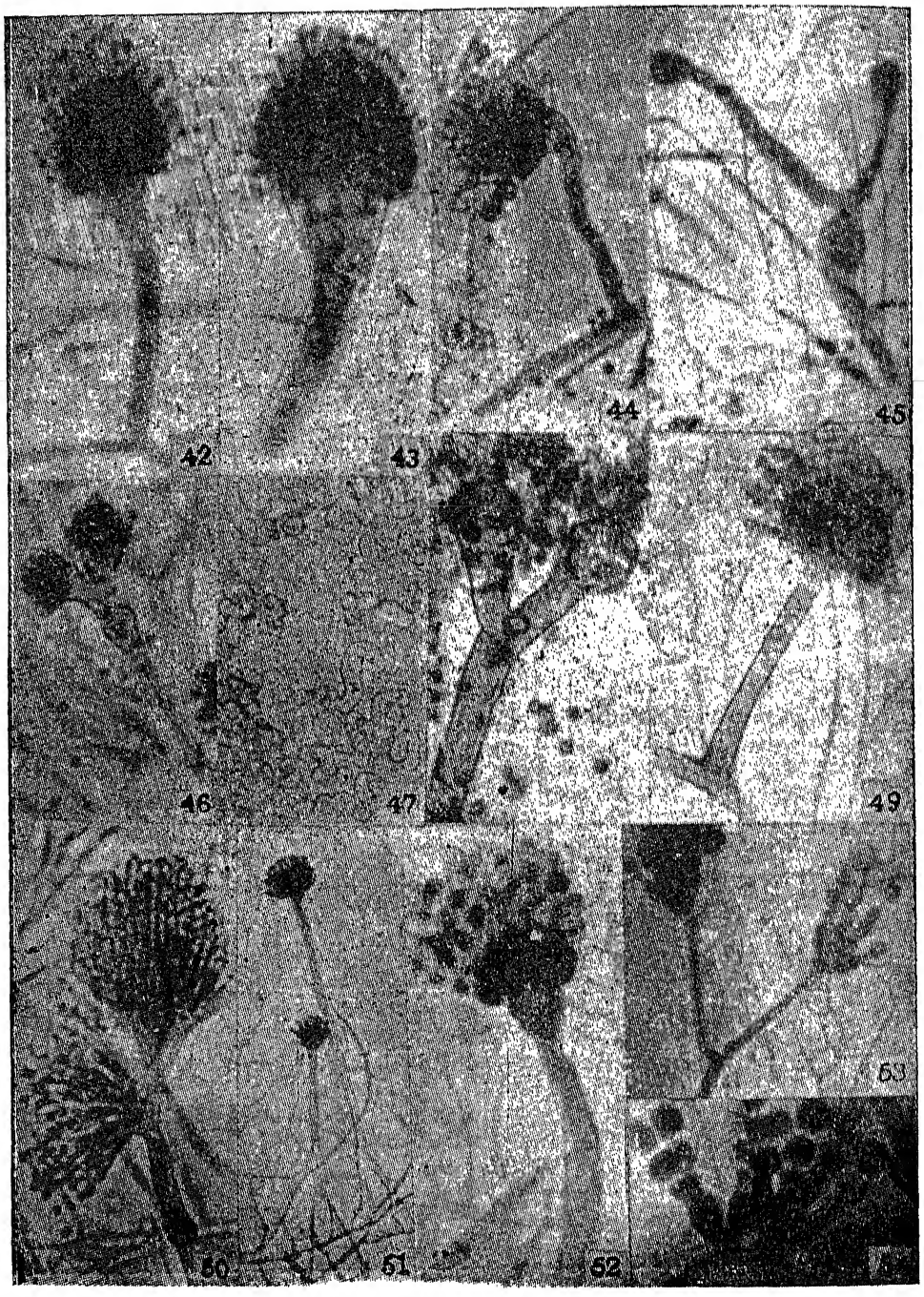
Aspergilli from India I

Figs. 1–21. *Aspergillus clavato-nanica, A. viridi-nutans* and *A. puniceus* (Camera-lucida drawings).



Aspergilli from India I

Figs. 22–41. *A. terreus* var. *aureus*, *A. flavus* var. *columnaris*, and *A. oryzae* var. *effusus* (Camera lucida-drawings).



Aspergilli from India 1

Fig. 42–54. *A. clavato-nanica*, *A. viridi-nutans*, *A. puniceus*, *A. terreus* var. *aureas*, *A. flavus* var. *columnaris* and *A. oryzae* var. *effusus* (Photomicrographs)

LEGENDS

Figs. 1–7 *Aspergillus clavato-nanica* (camera lucida drawings). 1–3 : Developmental stages of a young conidiophore, x 1450. 4 : Upper portion of a mature conidiophore, x 580. 5 : A short conidiophore, x 1450. 6 : Upper portion of an aerially borne conidiophore, x 1450. 7 : Conidia, x 1450.

Figs. 8–13. *Aspergillus viridi-nutans* (camera lucida drawings). 8 : An immature young conidiophore, x 1450. 9–12 : Developmental stages of a young conidiophore, x 1450. 13 : Conidia, x 1450.

Figs. 14–21. *Aspergillus puniceus* (camera lucida drawings). 14–16 : Developmental stages of a young conidiophore, x 1450. 17 : A typical foot cell, x 1450. 18 : Upper portion of a mature conidiophore, x 1450. 19 : A much reduced mature conidiophore, x 1450. 20 : Conidia, x 1450. 21 : Hulle cells, x 1450.

Figs. 22–29. *Aspergillus terreus* var. *aureus* (camera lucida drawings). 22–24 : Developmental stages of a young conidiophore, x 1450. 25 : sterigmata, x 1450. 26 : Upper portion of a mature conidiophore, x 1450. 27 : Conidia, x 1450. 28 : Upper portion of a branched conidiophore, x 560. 29 Upper portion of a proliferating conidiophore with three secondary heads, x 580.

Figs. 30–36. *Aspergillus flavus* var. *columnaris* (camera lucida drawings). 30–31 : Developmental stages of a young conidiophore, x 1450. 32 : conidia, x 1450. 33 : Upper portion of a mature conidiophore, x 1450, 34 : A short mature conidiophore, x 1450. 35 : Upper portion of a branched conidiophore, x 580. 36 : A mature conidiophore, x 580.

Fig. 37–41. *Aspergillus oryzae* var. *effusus* (camera lucida drawings). 37–39 : Developmental stages of a young conidiophore, x 1450. 40 : Conidia, x 1450. 41 : A mature branched conidiophore with single and double series of sterigmata, x 1450.

Fig. 42-43. *Aspergillus clavato-nanica* (photomicrographs). 42 : A short mature aerial conidiophore, x 640. 43 : Upper portion of a submerged conidiophore x 640.

Figs. 44–46. *Aspergillus viridi-nutans* (photomicrographs). 44 : A typical mature conidiophore, x 640. 45–46 : Young and mature proliferating conidiophores, with two secondary heads, x 640.

Fig. 47-49. *Aspergillus puniceus* (photomicrographs). 47 : Elongate, curved or variously twisted hulle cells, x 160. 48 : Upper portion of a branched conidiophore, x 800. 49 : A short mature conidiophore, x 640.

Fig. 50. *Aspergillus terreus* var. *aureus* (photomicropraph). 50 : Upper portion of a branched conidiophore, x 640.

Figs. 51–52. *Aspergillus flavus* var. *columnaris* (photomicrographs). 51 : Two young conidiophores, x 160. 52. Upper portion of a mature conidiophore, x 640.

Figs. 53–54. *Aspergillus oryzae* var. *effusus* (photomicrographs). 53 : Upper portion of a branched conidiophore, x 200. 54 : Reduced conidial heads developing on an aerial hypha, x 640.

areas sufficiently raised above, then greenish glaucous to pois green (R., Plate XLI), reverse almost colourless to light yellow. Conidial heads columnar, 30–55 by 18–30μ, conidiophores arising from the substrate or aerial hyphae, thin walled, smooth, unbranched, more or less sinuous, when submerged 30–50 by 2·4·8μ, when aerial 15–35 by 2-4·0μ ; vesicles subglobose to flask-shaped, 5–16·5μ, mostly 9–12μ in diameter, usually borne at an angle on the conidiophore, presenting a nodding appearance, while others show the same upright condition ; sterigmata uniseriate borne on the upper half of vesicle, 4·5–6·7 by 1·8-2·2μ, mostly 5–6 by 2·2μ ; occasionally sterigmata borne on secondary vesicles formed as a result of proliferation of the primary vesicle on short conidiophores presenting the same nodding appearance ; conidia globose to subglobose, delicately roughened, light green, 1·8–2·7μ, mostly 2·2μ in diameter.

Colonies on malt agar growing rapidly at 25°C (±1°C), attaining a diameter of 4–6 cms. in 7–10 days, more or less floccose, corydalis green (R., Plate XLI) to pea green (R., Plate XLVII), reverse light viridine green (R., Plate VI) to massicot yellow (R., Plate XVI). Conidial structures almost duplicating as that on Czapek's agar except that the aerially borne conidiophores are produced more frequently than the submerged ones.

Description based upon culture No. Ax-42, isolated from farm soil, pH 6·8, of Bhagwanpur (Bihar). Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate resembles almost in all respects with the type description given by Ducker and Thrower. However the proliferation of secondary heads, though uncommon, was not reported before.

Aspergillus puniceus Kwon and Fennell, in The Genus Aspergillus, 547-550, Fig. 122A–D (1965).

Colonies on Czapek's solution agar growing well at 25°C (± 1°C), attaining a diameter of 3–5 cms. in 7–10 days and consisting more or less of aerial floccose mycelium with compact basal felt, at first colourless to creamy, then hydrangea pink (R., Plate XXVII) to vinaceous pink (R., Plate XXVIII) and finally mikado brown (R., Plate XXIX) to snuff brown (R., Plate XXIX), reverse colourless to citron yellow (R., Plate XVI) and finally honey yellow (R., Plate XXX), exudate in the form of few to many droplets, pink to wine red in colour. Conidial heads globose to radiate when young to short columnar at maturity, ranging 45–120 by 105–150μ, mostly 90 by 120 μ ; conidiophores brownish, smooth, sometimes sinuate or occasionally recurved, mostly unbranched but rarely branched also, developing from the submerged mycelium or from the trailing hyphae, when submerged mostly 120–300 by 4·5–7·5μ, occasionally upto 400 by 7–8μ, when aerial mostly 60–105 by 3–4·5μ ; vesicles subglobose to somewhat elongate, ranging 7·5–15μ in diameter when subglobose and 15–19·5 by 10·5–1[illegible]μ when elongate, sterigmata in two series, arranged on the upper three-fourth surface of vesicle, primaries mostly 4·5–5·2 by 3μ but ranging 4·5-6·0 by 2·2–3·0μ, secondaries mostly 6–6·8 by 2·2μ but ranging 4·5–9 by 1·5–3·0μ ; conidia globose to subglobose, roughened, mostly 3·0–3·3μ in diameter but ranging 2·2–3·5μ in diameter, yellowish green to vinaceous ; hulle cells abundant, forming conspicuous masses associated with brightly pigmented yellow mycelium, elongate, crescent shaped, or irregularly twisted.

Colonies on malt extract agar spreading rapidly, attaining a diameter of 5–6 cms. within 7–10 days, at first colourless, later vinaceous buff (R., Plate XL) and finally ochraceous salmon (R., Plate XV) to dresden brown (R., Plate XV),

reverse cream buff. Conidial structures almost the same as described above, nulle cells forming more conspicuous yellow masses and overgrown by aerial hyphae bearing conidial heads.

Description based on culture No. Ax-43, isolated from farm soil, pH 6·8, of Bhagwanpur (Bihar). Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate resembles with the type description except for the branching of conidiophores which is rare.

Aspergillus terreus var. *aureus* Thom and Raper in A Manual of the Aspergilli, 198–200, Fig. 57B (1945).

Colonies on Czapek's solution agar comparatively slow growing, more or less floccose, attaining a diameter of 2–3 cms. in 7–10 days at 25°C (± 1°C), at first colourless later becoming pale ochraceous buff (R., Plate XV) to cream buff (R., Plate XXX), reverse ochraceous buff (R., Plate XV) to cinnamon buff (R., Plate XXIX). Conidial heads columnar, 105–200 by 30–50μ, conidiophores either submerged or developing from aerial hyphae, when submerged 150–375 by 5–9μ, mostly 250–300 by 6μ, when aerial 165–1050 by 4·5–7·5μ, mostly 525–750 by 7·5μ, thin walled, smooth, colourless with uniform width throughout, mostly unbranched, rarely branched and proliferating; vesicles globose, subglobose to dome like, 9–19·5μ, mostly 12–15μ in diameter; sterigmata in two series, primaries almost parallel, 3·7–7·5 by 2·2–3·7μ, mostly 6 by 3μ, secondaries crowded and loosely packed, 6–9 by 1·5–2·2μ, mostly 7·5 by 1·5–2·2μ; conidia globose to subglobose, rarely slightly elliptical, small, ranging 1·8–2·7μ, mostly 2·2μ in diameter.

Colonies on malt extract agar slightly more floccose and attaining a diameter of 3–4 cms. at 25°C (± 1°C) in 7–10 days. Conidial heads columnar, ranging from ochraceous buff (R., Plate XV) to cream buff (R., Plate XXX), reverse ochraceous salmon (R., Plate XV) to cinnamon (R., Plate XXIX). Conidial structures almost the same as described on Czapek's agar.

Description based on culture No. Ax-44, isolated from farm soil, pH 7·0, Agricultural Institute, Naini, Allahabad. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate resembles with the type description given by Raper and Fennell except for the aerially borne conidiophores which are rarely branched and reach upto 1 mm. or more in length.

Aspergillus flavus Link var. *columnaris* Raper and Fennell, in The Genus Aspergillus, 366–369, Fig. 75 C, F (1965).

Colonies on Czapek's solution agar growing rapidly at 25°C (± 1°C), reaching 4–6 cms. in diameter in 7–10 days, close textured and velvety at first light yellow green to courge green (R., Plate XVII) and finally chromium green (R., Plate XXXII) to rainette green (R., Plate XXXI), reverse almost colourless. Conidial heads columnar, ranging 120–450 by 60–120μ, mostly 250–300 by 7·5–9μ; conidiophores hyaline, thin walled, finally roughened, unbranched but rarely branched also, ranging 150–375 by 4·5–9·0μ, mostly 180–225 by 6·0μ; vesicles elongate when young later subglobose, hyaline, thin walled, varying from 7·5–30·0μ in diameter, mostly 15–19·5μ in diameter; sterigmata in single series ranged on the upper part of the vesicle, 7·5–12·0 by 2·8–4·0μ, mostly 9–10·5 by 3μ, rarely in double series also and then primaries 7–9 by 3·3–4·2μ and secondaries

8–10 by 2·8–3·0μ ; conidia globose, subglobose to ovate, varying from 3·3–6·0μ in diameter, mostly 4·5μ in diameter, echinulate, yellow green.

Colonies on malt agar growing more rapidly than on Czapek's agar at 25°C (± 1°C) and attaining a diameter of 5–7 cms. in 7–10 days, plane, velvety, at first lime green to mignonette green and finally kronberg's green (R., Plate XXXI) to yellowish olive (R., Plate XXX). Conidial heads predominantly columnar, ranging 300–650 by 60–150μ. Other structures as described on Czapek's solution agar.

Description based on culture No. Ax–45, isolated from garden soil, pH 7·0, Botany Department, University of Allahabad. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate resembles with the type description given by Raper and Fennell except for the slight differences in the measurements of vesicles, sterigmata and conidia. Also the branching of conidiophores reported here was not described earlier.

Aspergillus oryzae (Ahlb.) Cohn var. *effusus* (Tiraboschi) Ohara, in Key only in Research Bull. Fac. Agr., Gifu Univ., No. 1, p. 81 (1951).

Colonies on Czapek's solution agar growing rapidly at 25°C (± 1°C), attaining a diameter of 4–6 cms. in 7–10 days, more or less floccose with relatively profuse production of conidial heads originating from the loose aerial mycelium, at first colourless but slowly passing through shades of pale pinkish buff (R., Plate XXIX) to barium yellow (R., Plate XVI) or cream buff (R., Plate XXX). Conidial heads globose to radiate, 45-120μ in diameter, splitting into conidial columns in age ; conidiophores comparatively much smaller, hyaline, smooth or sometimes rough walled, mostly unbranched, occasionally once branched, 30–300 by 4·5–7·5μ, mostly 120 by 6μ, rarely more and then upto 1 mm. in length but sometimes reduced or absent also, often thin trailing hyphae may also form smaller heads with reduced vesicles ; vesicles generally small, globose to subglobose or somewhat elongate, ranging 7·5–20·5μ, rarely upto 30μ in diameter, mostly 12–15μ in diameter, hyaline and thin walled ; sterigmata generally in single series, ranging 7·5–13·5 by 3·7–6μ, mostly 10–12 by 4·5μ in diameter, rarely in two series, and then primaries 9–15 by 4·5–6μ, secondaries 12–15 by 4·5–6μ ; conidia globose to subglobose, ranging 4·5–7·5μ, mostly 6μ in diameter, smooth when young but roughened at maturity. Sclerotia or cleistothecia not seen.

Colonies on malt extract agar developing more vigorously with aerially borne conidial heads, filling the entire area of Petri dish in 7–10 days at 25°C (± 1 C), at first light to pale ochraceous salmon (R., Plate XV), later changing into light pinkish cinnamon to light vinaceous cinnamon (R., Plate XXIX), reverse in cream colour to naples yellow shades (R., Plate XVI). Other characters same as described on Czapek's solution agar.

Description based on culture No. Ax–46, isolated from farm soil, pH 6·8, Sasaram (Bihar). Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate resembles with the type description given by Raper and Fennell (1965). However, the occasional presence of branched, short or reduced conidiophores seen in this isolate was not reported earlier.

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Chromosome studies of fifteen species of Indian Digenetic Trematodes*

By

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Introduction

Trematode taxonomy has been a fascinating problem since long and in recent times it has led to the accumulation of a vast literature in this subject. The taxonomic studies based only on morphological data have produced considerable difficulties because it has not helped much to understand the limits of individual variations in a species. No wonder that in recent times cytological studies have become an important tool in the hands of taxonomists who supplement the morphological studies with cytological data. In fact a stage has come when one has necessarily to base the relationships within natural groups of species on sound cytological studies. The karyotype has been recognized as a definite species character, the morphology of the chromosomes among the individuals of the same species being reasonably constant.

Our knowledge of chromosomes in various groups of trematodes is meagre. Mostly such reports have been made along with their works on gametogenesis and germ cell cycle. A first definite review of chromosome studies in digenetic trematodes was done by Britt (1947). He described the number and behaviour of the chromosomes in species representing eight families and analysed reports on chromosome numbers in ten other families of digenetic trematodes. Contributions of Jones (1945), Britt (1947) and Short and Menzel (1960) were primarily concerned with gathering cytological evidence to show an evolutionary mechanism in Platyhelminthes. Citing evidence based on chromosome number, Britt (1947) supported McMullen's suggestion (1937) that the family Lecithodendriidae shows relationship with the families Plagiorchiidae and Reniferidae and that they should be kept in the same superfamily. However, he did not support Dollfus (1930) and Faust (1939) in placing Allocreadiidae in the same superfamily with Plagiorchiidae. Analysing the work on fifty species of various genera and families, Britt suggested 'Aneuploidy' as a major factor in the evolution of the digenetic trematodes and other hermaphroditic animals. Walton (1959) reviewed the various studies on chromosome numbers of some parasites including trematodes. Gresson (1964) gave further critical analysis of the chromosome studies of the digenetic trematodes recorded upto that time and supported Britt in his conclusions that there is no evidence of polyploidy within the digenea, and that variations of diploid number is probably due to the addition or loss of chromosomes.

Lindner (1914) gave the first account of sex chromosomes in *Schistosoma haematobium*. Lindner (1914) in *S. haematobium*, Faust and Meleney (1924) and

*Part of the thesis approved for Ph.D. degree, University of Jabalpur, 1963.

Severinghaus (1928) in *S. japonicum* reported the differences in chromosome number between the sexes and indicated male, as heterogametic. Severinghaus (1928) gave an experimental evidence to show that the miracidium can give rise to sporocyst and cercaria of its own sex. However, Ikada and Makino (1936) in *S. japonicum* and Niyamasena (1940) in *S. mansoni* could not ascertain the difference in chromosome number between the sexes. They failed to see morphologically distinguishable sex chromosomes in these species. Short and Menzel (1960) studied the chromosomes in cercarial embryos in nine species of schistosomes belonging to six genera. Their results agree with those of Ikeda and Makino (1936) on *S. japonicum* and Niyamasena (1940) on *S. mansoni* in respect of chromosome number. They also failed to detect heterochromosomes. Howevers, they reported a heteromorphic pair of chromosomes in the female *Schistosomatium douthitti* and in *Ornithobilharzia canaliculata*. In these blood flukes both X and Y chromosomes have been identified cytologically in the female. According to these authors the cytological evidence of female heterogamety in the two genera of Schistosomes suggests that this condition prevails throughout the family, but the morphological differences detectable at mitosis between X and Y have not developed in some genera. They further stated that "the fundamental similarity of karyotypes in nine species of six genera studied supports the hypothesis that the Schistosomes are a monophyletic group."

The present work deals with the chromosome studies of fifteen species representing fourteen genera and eleven families. The chromosome numbers of other species of digenetic trematodes, which are already known, have also been reviewed for comparison.

Material and Method

The parasites were collected from different hosts as given below :

Diplodiscus amphichrus magnus Srivastava, 1934 from the rectum of *Rana tigrina* Daud ;

Mehraorchis ranarum Srivastava, 1934 from the intestine of *R. tigrina* Daud and *R. cyanophlyctis* Schneid ;

Ganeo kumaonensis Pande, 1937, *Pleurogenoides orientalis* (Srivastava, 1935) and *Prosotocus kashabia* Kaw, 1943 from the intestine of *R. tigrina* Daud ;

Halipegus mehransis Srivastava, 1933 from the stomach of *Rana cyanophlyctis* Schneid ;

Encyclometra colubrimurorum (Rud. 1819) Dollfus, 1929, *Ommatobrephus lobatum* Mehra, 1928, *Proalarioides tropidonotis* Vidyarthi, 1937 and *Gogatea serpentium* (Gogate, 1932) Lutz, 1935 from the intestine of *Tropidonotus piscator* ;

Paradistomum orientalis (Narain and Das, 1929) from the gall bladder of *Calotes versicolor* Daud ;

Cephalogonimus amphiumae Chandler, 1923 from the intestine of *Trionyx gangeticus* ;

Genarchopsis singularis and *G. lobatum* (Srivastava, 1933) from the stomach of *Ophicephalus punctatus* Bloch ; and

Orientocreadium umadasi Saksena, 1960 from the intestine of *Clarias batrachus* Linn.

For a comparative study of chromosomes in different species it was felt desirable to adopt a uniform method of chromosome preparation. Fresh material was fixed in Carnoy's fixative (1 Part glacial acetic ; 3 Parts of absolute alcohol)

for six hours. Temporary iron-aceto-carmine squashes of small pieces of testis, ovary and the eggs (dissected out from the proximal part of the uterus) were prepared. The material was protected from drying by sealing the slide with aceto-gelatine solution (Darlington and La Cour, 1942).

The idiograms were constructed from the measurements of mitotic chromosomes and represent only the four pairs in order of their length from the complement.

Observations

The chromosome counts were made from the mitotic and meiotic metaphase plates of dividing cells during the process of gametogenesis. The first cleavage of the zygote gives the best results for the study of mitotic chromosomes. Four chromosomes of maximum length for each species are represented diagrammatically in the idiograms of Fig. 40.

The total number of species studied and the number of plates analysed are incorporated in Table I.

TABLE I

	Name of parasite	Number Examined	Mitotic plates studied		Meiotic plates studied	
			During Gametogenesis	During Ist cleavage	Mat. div. of spermatocytes	Mat. div. of oocytes
1.	*Diplodiscus amphichrus magnus*	40	20	2	35	12
2.	*Paradistomum orientalis*	35	14	25	30	6
3.	*Mehraorchis ranarum*	10	7	4	15	10
4.	*Ganeo kumaonensis*	30	6	10	8	15
5.	*Pleurogenoides orientalis*	12	5	2	4	6
6.	*Prosotocus kashabia*	6	3	4	2	4
7.	*Encyclometra colubrimurorum*	7	19	20	18	9
8.	*Ommatobrephus lobatum*	2	–	–	5	1
9.	*Cephalogonimus amphiumae*	10	–	3	–	–
10.	*Orientocreadium umadasi*	20	3	–	2	4
11.	*Proalarioides tropidonotis*	12	6	1	8	4
12.	*Gogatea serpentium*	20	21	–	4	–
13.	*Genarchopsis singularis*	22	6	20	12	7
14.	*G. lobatum*	10	1	15	14	4
15.	*Halipegus mehransis*	25	–	32	14	16

Family : Paramphistomatidae Fischoedar, 1901.

1. *Diplodiscus amphichrus magnus* Srivastava, 1934.

The haploid number of the chromosomes is nine and the diploid number is eighteen in this species (Figs. 1, 2).

The chromosomes fall into three distinct groups. There are three pairs of large chromosomes 3·5 – 6·5μ in length ; three pairs of medium sized chromosomes, 2·5 – 4·75μ in length and the three small pairs, 1·0 – 2·5μ in length.

Further critical analysis gives the following results :

(*i*) The first and second pairs of large chromosomes are V-shaped with equal arms and median centromeres. The first pair of chromosomes has a secondary constriction.

(*ii*) Third pair of large chromosomes and the fourth and the fifth pairs of chromosomes of medium size have unequal arms and submedian centromeres.

(*iii*) The sixth pair is metacentric with equal arms.

(*iv*) The rest of the chromosomes are small and rod-shaped.

Fig. 1.

Fig. 2.

Diplodiscus amphichrus magnus

Fig. 1. Metaphase chromosomes of primary spermatocyte.

Fig. 2. Metaphase chromosomes of spermatogonium.

Family : Dicrocoeliidae Odhner, 1910.

2. *Paradistomum orientalis* (Narain and Das, 1929).

The haploid number of the chromosomes is thirteen and the diploid number is twenty-six in this species (Figs. 3, 4, 5, 6, 7).

(*i*) There are four pairs of large chromosomes measuring 3·5 – 7·5μ in length. They are sub-metacentric with unequal arms. The second pair of large chromosomes has a secondary constriction.

(*ii*) The fifth, sixth and the seventh pairs are of medium size, measuring 2·5 – 5·5μ in lenght. Some of them are metacentric while others are rod-shaped.

(*iii*) The rest of the chromosomes are small, rod-shaped or dot-shaped measuring 1·0 - 3·0μ in length.

Fig. 3.

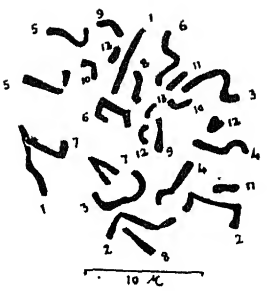

Fig. 4.

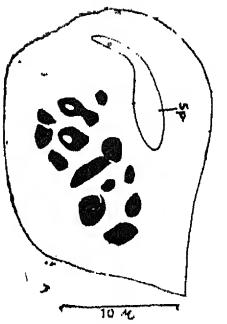

Fig. 5.

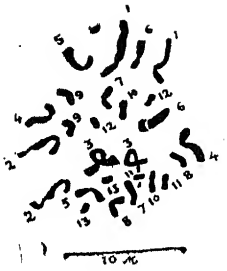

Fig. 6.

Fig. 7.

Paradistomum orientalis

Fig. 3. Primary spermatocyte, diplotene stage.
Fig. 4. Primary spermatogonium, late prophase.
Fig. 5. Metaphase chromosomes of primary oocyte.
Fig. 6. Metaphase chromosomes of the first cleavage of zygote.
Fig. 7. Metaphase chromosomes of primary spermatogonium.

Family : Lecithodendriidae Odhner, 1910.

3. *Mehraorchis ranarum* Srivastava, 1934.

The haploid number of the chromosomes is eleven and the diploid number is twenty-two in this species (Figs. 8, 9, 10). Critical analysis of the chromosomes gives the following results :

(*i*) The first pair of chromosomes is the largest, measuring 4·0 – 9·5μ in length. They are metacentric with equal arms.

(*ii*) The second pair measures 3·0 – 6·5μ in length. It is sub-metacentric with unequal arms.

(*iii*) The third, fourth, fifth, sixth and the seventh pairs of chromosomes are of medium size, measuring 2·0 – 4·5μ in length. Some of them are sub-metacentric with unqual arms.

(*iv*) The rest of the chromosomes are small, rod-shaped, measuring 0·5 – 2·0μ in length. Some of them are metacentric.

Fig. 8.

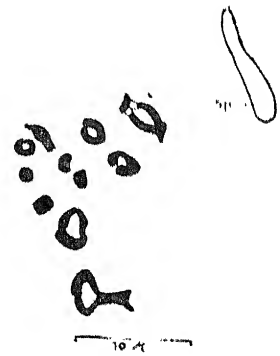

Fig. 9.

Fig. 10.

Mehraorchis ranarum

Fig. 8. Metaphase chromosomes of primary spermatocyte.
Fig. 9. Metaphase chromosomes of primary oocyte.
Fig. 10. Metaphase chromosomes of oogonium.

4. *Ganeo kumaonensis* Pande, 1937.

The haploid number of the chromosomes is ten and the diploid number is twenty in this species. (Figs. 11, 12, 13,) :

(*i*) The first pair is the largest, measuring 2·5 – 5·5μ in length. It is sub-metacentric with unequal arms.

(*ii*) The second pair is metacentric, measuring 2·5 – 4·0μ in length.

(*iii*) The third (sub-metacentric), fourth and the fifth (metacentric) pairs are of medium size, measuring 1·25 – 3·25μ in length.

(*iv*) The rest of the chromosomes are small, rod-shaped, measuring 0·6 – 2·0μ in length.

Fig. 11.

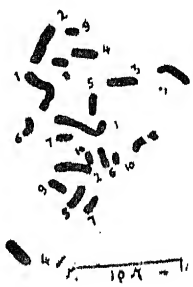

Fig. 12.

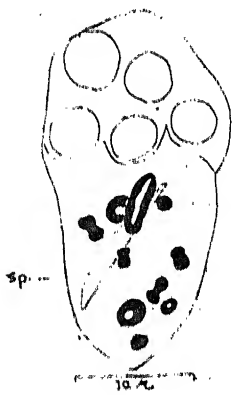

Fig. 13.

Ganeo kumaonensis.

Fig. 11. Metaphase chromosomes of primary spermatocyte.
Fig. 12. Metaphase chromosomes of primary spermatogonium.
Fig. 13. Early anaphase chromosomes of primary oocyte. Sperm seen in the cytoplasm.

5. *Pleurogenoides orientalis* (Srivastava, 1934).

The haploid number of chromosomes is nine and the diploid number eighteen in this species. (Figs. 14, 15).

The first two pairs of chromosomes are metacentric (or slightly sub-metacentric), V-shaped, measuring 2·5 - 3·5μ in length.

The third, fourth, fifth and the sixth pairs of chromosomes are also metacentric, measuring 1·5 – 2·5μ in length.

The rest of the chromosomes are small, rod-shaped or dot-shaped, measuring 0·5 – 1·25μ in length.

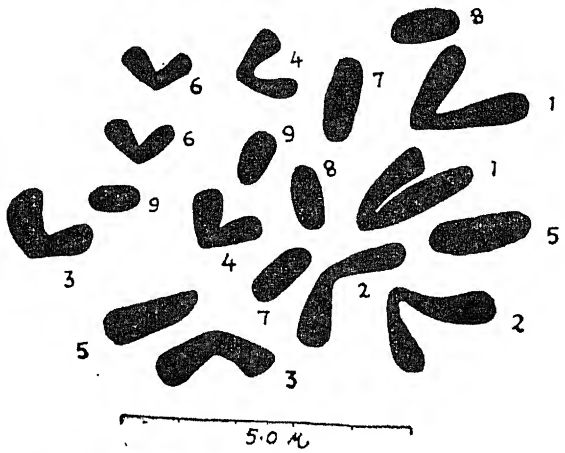

Fig. 14.

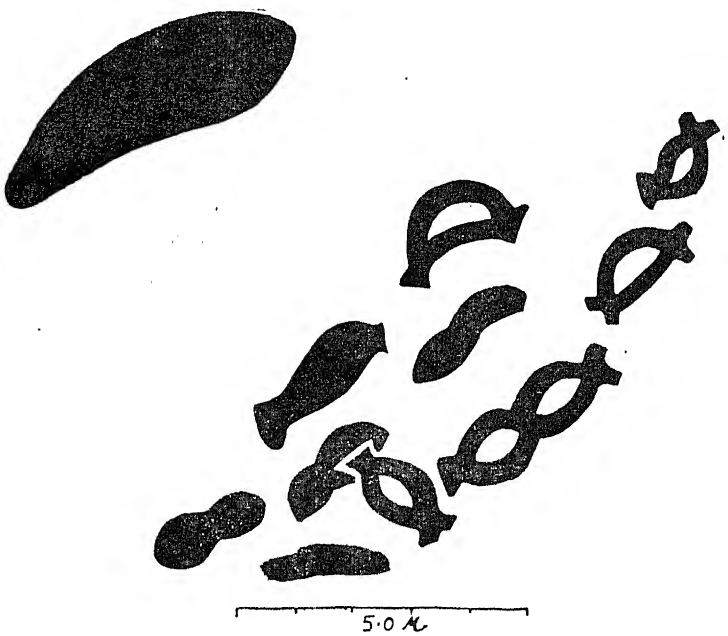

Fig. 15.

Pleurogenoides orientalis.

Fig. 14. Metaphase chromosomes of se condary spermatogonium.

Fig. 15. Primary oocyte in diplotene stage, sperm lying by the side.

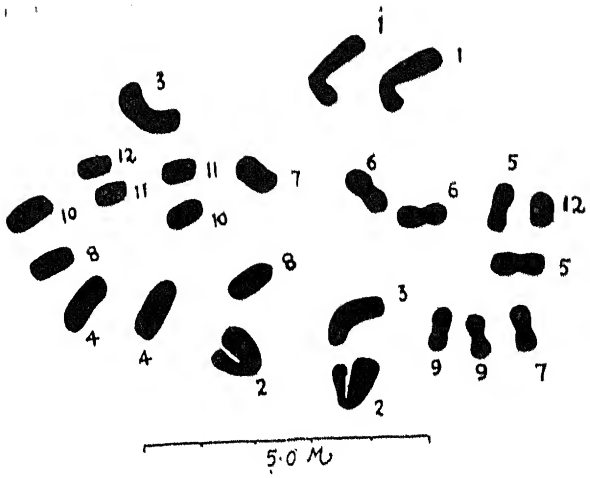

Fig. 16

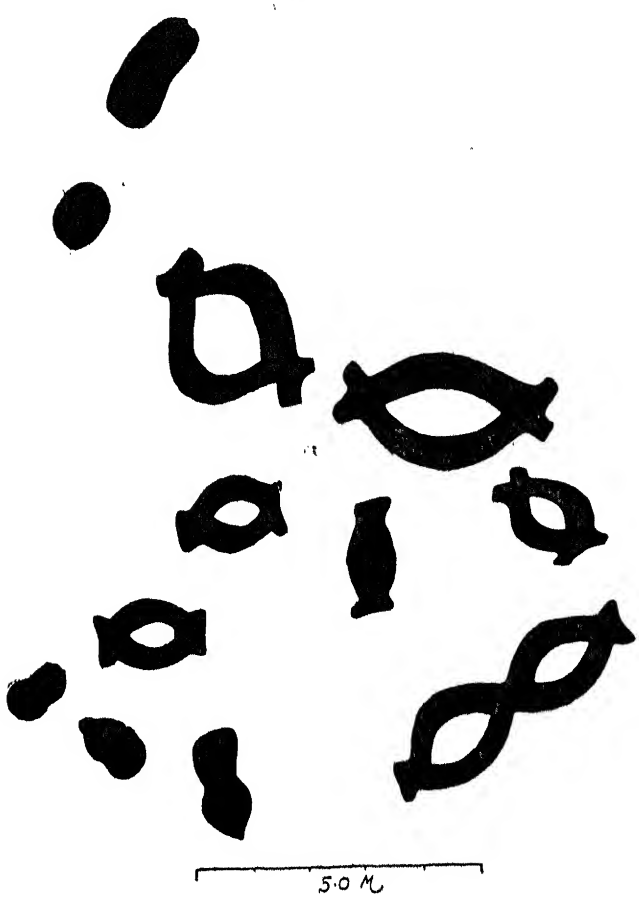

Fig. 17

Prosotœcus kashabia.

Fig. 16. Metaphase chromosomes of first cleavage.
Fig. 17. Primary oocyte in diplotene stage.

6. *Prosotocus kashabia* Kaw, 1943.

The diploid number of chromosomes is twenty-four and the haploid number is twelve in this species. (Figs. 16, 17)

There are two pairs of chromosomes measuring 1·5 – 2·0μ in length, one of which is sub-metacentric, J-shaped, while the other is metacentric, V-shaped.

The third and the fourth pairs measure 1·0 – 1·5μ in length. They are metacentric.

The rest of the chromosomes are small, rod-shaped or dot-shaped, measuring 0·6 – 1·0μ in length.

Family : Plagiorchiidae Luhe, 1901, emend, Ward, 1917.

7. *Encyclometra colubrimurorum* (Rud. 1819) Dollfus, 1929.

The haploid number of chromosomes is six and the diploid number is twelve in this species (Figs. 18, 19, 20, 21, 22).

The first pair of chromosomes is sub-metacentic, J–shaped, measuring 4·5 – 8·0μ in length.

The second, third and the fourth pairs of chromosomes are also sub-metacentric with unequal arms, ranging from 3·25 to 7·0μ in length.

The fifth and the sixth pairs measure 2·0 – 5·0μ in length, one of which is metacentric, while the other is sub-metacentric.

Fig. 18.

Fig. 19.

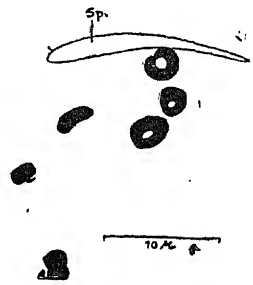

Fig. 20.

Fig. 21.

Fig. 22.

Encyclometra colubrimurorum

Fig. 18. Metaphase chromosomes of primary spermatocyte.
Fig. 19. Metaphase chromosomes of primary spermatogonium.
Fig. 20. Metaphase chromosomes of primary oocyte.
Fig. 21. Metaphase chromosomes of secondary oocyte.
Fig. 22. Metaphase chromosomes of first cleavage.

Family : Ommatobrephidae Pocli, 1962.

8. *Ommatobrephus lobatum* Mehra, 1928.

Only haploid stages could be studied in this species. The haploid number of chromosomes six is and so the diploid number is twelve in this species. (Fig. 23).

Family : Cephalogonimidae Nicoll, 1915.

9. *Cephalogonimus amphiumae* Chandler, 1923.

The diploid number of chromosomes is sixteen and the haploid number is eight in this species (Fig. 24). The chromosomes fall into three distinct groups :

(*i*) The first three pairs of chromosomes are of large size measuring 3·5 - 4·5μ in length.

(*ii*) The fourth pair is of medium size, measuring 2·0 - 2·5μ in length.

(*iii*) The rest of the chromosomes are small in size, measuring 0·6 – 1·0μ in length.

The first two pairs of chromosomes are metacentric and V-shaped. The third pair is sub-metacentric and J-shaped. The fourth pair is metacentric and V-shaped. The rest of the chromosomes are rod-shaped. Some of them are metacentric.

Fig. 23.

Fig. 24.

Ommatobrephus lobatum

Fig. 23. Metaphase chromosomes of primary spermatocyte.

Cephalogonimus amphiumae

Fig. 24. Metaphase chromosomes of first cleavage.

Family : Lepocreadiidae Nicoll, 1934.

10. *Orientocreadium umadasi* Saksena, 1960.

The haploid number is ten and the diploid number is twenty in this species (Fig. 25, 26).

The first pair of chromosomes is metacentric, V-shaped, measuring 2·0 – 2·5μ in length.

The second, third, fourth and the fifth pairs are rod-shaped, measuring 1·0 – 1·5μ in length.

The rest of the chromosomes are small, rod-shaped or dot-shaped, measuring 0·5 – 1·0μ in length.

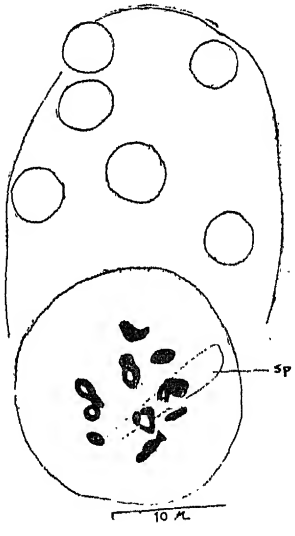

Fig. 25.

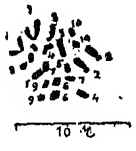

Fig. 26.

Orientocreadium umadasi

Fig. 25. Metaphase chromosomes of primary oocyte, sperm lying in the cytoplasm.
Fig. 26. Metaphase chromosomes of secondary spermatogonia.

Family : Proterodiplostomatidae Dubois, 1937.

11. *Proalarioides tropidonotis* Vidyarthi, 1937.

The diploid number of the chromosomes is sixteen and the haploid number is eight in this species (Fig. 27).

(*i*) The first two pairs of chromosomes have unequal arms with sub-median centromeres. They measure 2·0 – 2·5μ in length.

(*ii*) The third, fourth and the fifth pairs of chromosomes are metacentric, measuring 1·5 – 2·0μ in length.

(*iii*) The rest of the chromosomes are small, rod-shaped, measuring 1·0 – 1·25μ in length.

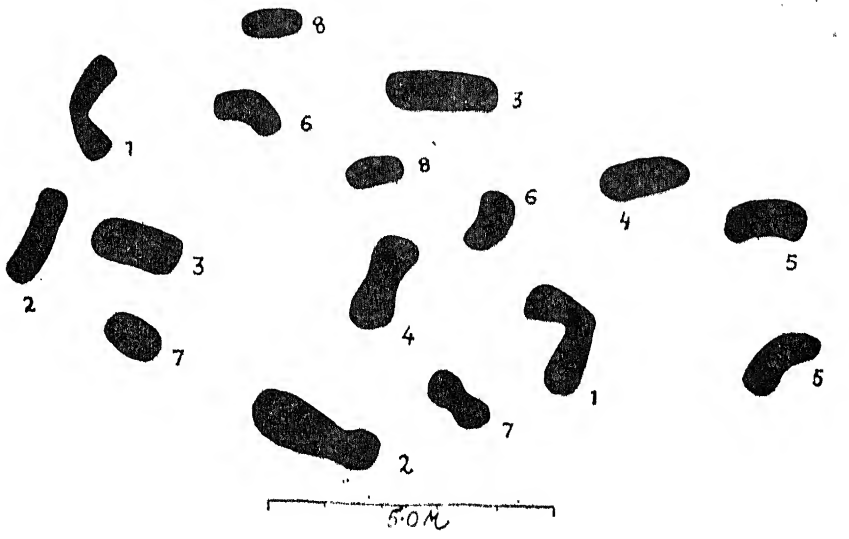

Fig. 27.

Proalarioides tropidonotis

Fig. 27. Metaphase chromosomes of primary spermatogonium.

Family : Cyathocotylidae Poche, 1926.

12. *Gogatea serpentium* (Gogate, 1932) Lutz, 1935.

The haploid number of chromosomes is eight and the diploid number is sixteen in this species (Figs. 28, 29, 30). The chromosome fall into three groups :

(*i*) Two pairs of large, metacentric chromosomes, 4·5 – 8·75μ in length.

(*ii*) The third pair of sub-metacentric chromosomes are of medium size, measuring 2·0 – 4·5μ in length.

(*iii*) Five pairs of small chromosomes which range from 0·6 to 2·5μ in length. Some of them are metacentric.

Fig. 28.

Fig. 29.

Fig. 30

Gogatea serpentium

Fig. 28. Diplotene chromosomes of primary spermatocyte.
Fig. 29. Metaphase chromosomes of primary spermatogonium.
Fig. 30. Metaphase chromosomes of spermatogonium.

Family : Hemiuridae Luhe, 1901.

13. *Genarchopsis singularis* (Srivastava, 1933).

The haploid number of chromosomes is ten and the diploid number is twenty for this species (Figs. 31, 32, 33, 34).

(*i*) The first pair of chromosomes is sub-metacentric, measuring 2·75 – 6·0μ in length. The long arm has a secondary constriction.

(*ii*) The second pair is metacentric, measuring 2·4 – 5·0μ in length.

(*iii*) The third and the fourth pairs of chromosomes are also metacentric, measuring 1·5 – 3·75μ in length.

(*iv*) The rest of the chromosomes are small, rod-shaped and range from 0·5 to 2·25μ in length. Some of them are metacentric.

Fig. 31.

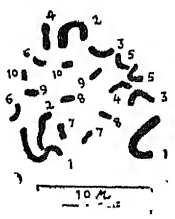

Fig. 32.

Fig. 33.

Fig. 34.

Genarchopsis singularis

Fig. 31. Primary spermatocyte in diakinesis.
Fig. 32. Metaphase chromosomes of primary spermatogonium.
Fig. 33. Metaphase chromosomes of primary oocyte.
Fig. 34. Metaphase chromosomes of first cleavage.

14. *Genarchopsis lobatum* (Srivastava, 1933).

The haploid number of chromosomes is ten and the diploid number is twenty in this species (Figs. 35, 36).

The morphology of the chromosomes is similar to that of *G. singularis* except that the size is slightly smaller. The first pair of chromosomes shows more chiasma frequency as compared to that of *G. singularis*.

(*i*) The first and the second pairs of chromosomes measure 2·25 – 4·5μ in length.

(*ii*) The rest of the chromosomes range from 0·5 – 2·5μ in length.

Fig. 35.

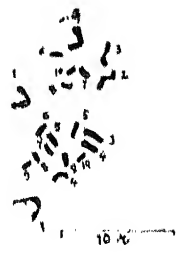

Fig. 36.

Fig. 37.

Fig. 38.

Fig. 39.

Genarchoptis lobatum

Fig. 35. Primary spermatocyte in diakinesis.
Fig. 36. Metaphase chromosomes of first cleavage.

Halipegus mehransis

Fig. 37. Metaphase chromosomes of primary spermatocyte.
Fig. 38. Metaphase chromosomes of primary oocyte.
Fig. 39. Metaphase choromosomes of first cleavage division.

Family : Halipegidae Poche, 1926.

15. *Halipegus mehransis* Srivastava, 1933.

The haploid number of chromosomes is eleven and the diploid number is twenty-two in this species (Figs. 37, 38, 39).

The chromosomes are comparatively small in size. The first pair of chromosomes measure 3·0 – 4·5μ in length. It is sub-metacentric and J-shaped. The second and third pairs show intermediate length (1·5 – 3·0μ). They are also sub-metacentric. The rest of the chromosomes are small ranging from0 ·5 to 1·5μ in length.

The following table lists the diploid and haploid chromosome numbers of the digenetic trematodes. The forms are arranged systematically according to the classification of La Rue (1957) and Mehra (1957, 1962). The authority for the data is also given in the table

TABLE II

Classification of the parasites	*n*	2*n*	Authority
1. *Order* : Echinostomida La Rue, 1957.			
(*i*) *Suborder* : Echinostomata Szidat, 1939.			
(*a*) *Superfamily* : Echinostomatoidea Faust, 1929.			
Family : Echinostomatidae Poche, 1926.			
Parorchis acanthus	11	22	Rees, 1939.
Family : Fasciolidae Railliet, 1895.			
Fasciola hepatica	6	12	Schubman, 1905.
	6-8♀		Henneguy, 1906.
	6	12	Schellenberg, 1911.
	6	12	Yosufzai, 1952.
	6	12	John, 1953.
	10	20	Sanderson, 1953, 1959.
	6	12	Govaert, 1960.
Fasciola gigantica	8	16	Srivastava *et al.* 1964*a*.
Family : Rhopaliadae Looss, 1899.			
Rhopalias macracanthus	8	16	Ciordia, 1949.
(*b*) *Superfamily* : Orchipedioidea Mehra, 1962.	Not reported.		
(*ii*) *Suborder* : Fellodistomata Singh, 1960.			
(*a*) *Superfamily* : Fellodistomatoidea La Rue, 1957.	Not reported.		
(*iii*) *Suborder* : Paramphistomata Szidat, 1939.			
(*a*) *Superfamily* : Paramphistomatoidea Stiles and Golberger, 1910.			
Family : Paramphistomatidae Fischoeder, 1901, emend, Goto and Matsudaira, 1918.			
Gigantocotyle bathycotyle	6	12	Willmott, 1950*b*.
Paramphistomum hibernae	6-8		Willmott, 1950*a*.
P. scotiae	8		Willmott, 1950*a*.
P. crassum	7	14	Srivastava *et al.* 1964*b*.
Zygocotyle lunata	7	14	Willey *et al.* 1951.
Gastrothylax crumenifer	7	14	Dhingra, 1955*b*.
Cotylophoron elongatum	8	16	Dhingra, 1955*a*.

Classification of parasites	*n*	2*n*	Authority.
Megalodiscus temperatus (= *Diplodiscus temperatus*)	9	18	Van der Woude, 1954.
Diplodiscus temperatus	8	16	Cary, 1909.
D. amphichrus magnus	9	18	Saksena, 1962.
Family : Heronimidae Ward, 1918.			
Heronimus chelydrae	10	20	Guilford, 1955.
(*b*) *Superfamily* : Notocotyloidea La Rue, 1957.			
Family : Notocotylidae Luhe, 1909.			
Notocotylus filamentis	7	14	Ciordia, 1950.
Family : Pronocephalidae Looss, 1902.			
Macravestibulum kepneri	9	18	Jones *et al.* 1945.
(*iv*) *Suborder* : Cyclocoelata La Rue, 1957.			
Superfamily : Cyclocoeloidea Nicoll, 1934.			
Family : Cyclocoelidae Kossack, 1911.			
Cyclocoelium bivesiculatum	10	20	Dhingra, 1954*c*.
(*v*) *Suborder* : Opisthorchiata La Rue, 1957.			
Superfamily : Ophisthorchioidea La Rue, 1957.			
Family : Heterophyidae Odhner, 1914.			
Cryptocotyle lingua	6	12	Cable, 1931, 1934
Acetodextra amiuri	6	12	Perkins, 1956.
(*vi*) *Suborder* : Renicolata La Rue, 1957.			
Superfamily : Renicoloidea La Rue, 1957. Not reported.			
(*vii*) *Suborder* : Plagiorchiata La Rue, 1957.			
(*a*) *Superfamily* : Plagiorchioidea Dollfus, 1930.			
Family : Dicrocoeliidae Odhner, 1910.			
Brachycoelium salamandrae	10	20	Kemnitz, 1913.
Dicrocoelium lanceatum	10	20	Goldschmidt, 1908. Dingler, 1910.
Paradistomum orientalis	13	26	Saksena, 1963.
Family : Lecithodendriidae Odhner, 1910.			
Acanthatrium pipistrella	11	22	Britt, 1947.
Loxogenes bicolor	11	22	Britt, 1947.
Brandesia turgidum	9	18	Levy, 1914.
Mehraorchis ranarum	11	22	Saksena, 1963.
Ganeo kumaonensis	10	20	Saksena, 1963.
Pleurogenoides orientalis	9	18	Saksena, 1963.
Prosotocus kashabia	12	24	Saksena, 1963.

Classification of the parasites	*n*	2*n*	Authority.
Family : Plagiorchiidae Luhe, 1901, emend. Ward, 1917.			
Eustomas chelydrae	9	18	Britt, 1947.
Glypthelmins quieta	9	18	Britt, 1947.
Plagitura salamandrae	11	22	Britt, 1947.
Pneumonoeces breviplexus	11	22	Britt, 1947.
P. mediaplexus	11	22	Pennypacker, 1936.
P. similiplexus	11	22	Pennypacker, 1940.
	11	22	Britt, 1947.
Encyclometra colubrimurorum	6	12	Saksena, 1963.
Family : Reniferidae Baer, 1924.			
Staphylodora bascaniensis	8	16	Britt, 1947.
Telorchis robustus	8	16	Britt, 1947.
Auridistomum chelydrae	9	18	Britt, 1947.
Dasymetra villicaeca	11	22	Britt, 1947.
Lechriorchis abduscens	11	22	Britt, 1947.
Natriodora verlatum	11	22	Britt, 1947.
Neorenifer aniarum	11	22	Britt, 1947.
N. drymarchon	11	22	Britt, 1947.
N. elongatus	11	22	Britt, 1947.
N. georgianus	11	22	Britt, 1947.
Neorenifer ovula	11	22	Britt, 1947.
N. wardi	11	22	Britt, 1947.
	11	22	Dunn, 1959.
Pneumatophilus leidyi	11	22	Britt, 1947.
P. variabilis	11	22	Britt, 1947.
Renifer ellipticus	11	22	Britt, 1947.
Telorchis corti	11	22	Britt, 1947.
T. lobosus	11	22	Britt, 1947.
T. medios	11	22	Britt, 1947.
Family : Ommatobrephidae Poche, 1926.			
Ommatobrephus lobatum	6	12	Saksena, 1963.
Family : Cephalogonimidae Nicoll, 1915.			
Cephalogonimus americanus	14	28	Britt, 1947.
C. amphiumae	8	16	Saksena, 1963.
(*b*) *Superfamily* : Allocreadioidea Nicoll, 1934.			
Family : Lepocreadiidae Nicoll, 1934.			
Orientocreadium umadasi	10	20	Saksena, 1963.
Family : Allocreadiidae Stossich, 1905.			
Allocreadium isoporum	8	16	Britt, 1947.
Crepidostomum serpentinum	8	16	Britt, 1947.
Sphaerostoma bramae	12	24	Gresson, 1958.

Classification of the parasites	*n*	2*n*	Authority
Family : Bunoderidae Nicoll, 1914			
Bunodera luciopercae	7	14	Britt, 1947.
B. saculata	8	16	Britt, 1947.
Family : Monorchiidae Odhner, 1911.			
Asymphylodora sp.	9	18	Dhingra, 1955*c*.
Family : Troglotrematidae Odhner, 1914.			
Paragonimus kellicotti	8	16	Chen, 1937.
Family : Zoogonidae Odhner, 1911.			
Zoogonus mirus	5	10	Goldschmidt, 1905, 1908.
	6	12	Schreiner, 1908. Gregoire, 1909. Wassermann, 1912, 1913.
2. *Order* : Strigeatoidea La Rue, 1926.			
(*i*) *Suborder* : Strigeata La Rue, 1926.			
(*a*) *Superfamily* : Strigeoidea Railliet, 1919.			
Family : Proterodiplostomatidae Dubois, 1937.			
Proalarioides tropidonotis	8	16	Saksena, 1963.
Family : Cyathocotylidae Poche, 1926.			
Gogatea serpentium	8	16	Saksena, 1963.
(*b*) *Superfamily* : Clinostomatoidea Dollfus, 1931.			
Family : Clinostomatidae Luhe, 1901, emend. Dollfus, 1932.			
Clinostomum marginatum	10	20	Britt, 1947.
(*c*) *Superfamily* : Schistosomatoidea Stiles and Haswell, 1926.			
Family : Schistosomatidae Looss, 1899. emend. Poche, 1907.			
Schistosomatium douthitti		14–	Short, 1957.
		(XXAA)♂	Short *et al.*
		14–	1960.
		(XYAA)♀	
Schistosoma mansoni	8	16	Niyamasena, 1940.
	8	16♂	Short *et al.* 1960.
	8	16♀	

Classification of the parasites	*n*	2*n*	Authority
S. haematobium	8– ♂,♀,I 8,6,– ♂II	16♀ 14♂	Lindner, 1914.
	8	16♂	Short *et al.* 1960.
	8	16♀	
S. japonicum	8♂I		Faust and Meleney, 1924.
	7,8♂II		
	8♂I	14♂	Severinghaus, 1928.
	(12*a*+2*x* = 14♂)		
	6,8♂II	16♀	
	(12*a* + 4*x* = 16♀)		
	8	16	Ikeda and Makino, 1936.
	8	16	Short and Menzel, 1960.
Ornithobilharzia canaliculata		16– (XXAA)♂	Short and Menzel, 1960.
		16– (XXAA)♀	
Trichobilharzia physellae	8	16	Short and Menzel, 1960.
T. stagnicolae A.	8	16	,,
T. stagnicolae B.	9	18	,,
Austrobilharzia variglandis	8	16♂	,,
Gigantobilharzia huronensis		16– ((XXAA)?♀	,,
		16– (XXAA)?♂	
Family : Spirorchiidae Stunkard, 1921.			
Spirorchis magnitestis	9	18	Jones and Mayer, 1953.
(*ii*) *Suborder* : Brachylaimata La Rue, 1957.			
(*a*) *Superfamily* : Brachylaimoidea Allison, 1943.	Not reported		
(*b*) *Superfamily* : Bucephaloidea La Rue, 1926.			
Family : Bucephalidae Poche, 1907.			
Bucephalus elegans	6	12	Woodhead, 1931
B. Pusillus	6	12	Woodhead, 1931.
Rhipidocotyle papillosum	6	12	Ciordia, 1956.

Classification of the parasites	*n*	2*n*	Authority
3. *Order* : Azygatoidea Mehra, 1957.			
(*i*) *Suborder* : Azygiata La Rue, 1957.			
(*a*) *Superfamily* : Azygioidea Skrj. Guschanskaja, 1956.			
Family : Azygiidae Odhner, 1911. emend. Dollfus, 1936.			
Azygia acuminata	9	18	Britt, 1947.
Proterometra macrostoma	9	18	Anderson, 1935. Britt, 1947.
(*b*) *Superfamily* : Transversotrematoidea La Rue, 1957.	Not reported.		
4. *Order* : Hemiuratoidea Mehra, 1957.			
Suborder : Hemiurata Skrj. and Guschanskaja, 1954.			
Superfamily : Hemiuroidea Faust, 1929.			
Family : Hemiuridae Luhe, 1901.			
Genarchopsis singularis	10	20	Saksena, 1963.
G. lobatum	10	20	Saksena, 1963.
Family : Halipegidae Poche, 1926.			
Halipegus occidualis	9	18	Jones, 1956.
H. eccentricus	11	22	Guilford, 1961.
H. mehransis	11	22	Saksena, 1963.
Family : Isoparorchiidae Poche, 1926.			
Isoparorchis eurytremum	10	20	Dhingra, 1954*a*
Isoparorchis hypselobagri	9	18	Srivastava *et al.* 1964*c*.
5. *Order* : Gorgoderida Mehra, 1958.			
Superfamily : Gorgoderoidea Mehra, 1958.			
Family : Gorgoderidae Looss, 1901.			
Probolitrema californiense	6	12	Markell, 1943.
Gorgoderina attenuata	7	14	Britt, 1947. Willey and Koulish, 1950.
Gorgodera amplicava	8	16	Britt, 1947.
Phyllodistomum spatula	8	16	Dhingra, 1954*b*.

Discussion

The stages of spermatogenesis, oogenesis and fertilization in the fifteen species belonging to fourteen genera as listed in the table I follow a common pattern. The process of spermatogenesis consists of three spermatogonial divisions and two maturation divisions. The resulting cells do not separate. They form clusters of 2, 4, 8, 16 and 32 cells. The thirtytwo spermatids ultimately develop into a bundle of 32 thread like sperms and leave behind a residual cytoplasm.

In some cases the nuclei, 2, 4, 8, 16 and 32 are observed lying in a common cytoplasmic mass without the formation of a rosette. The maturation of the oocyte begins in the ovary and it is completed in the proximal part of the uterus after the penetration of the sperm into the oocyte. Early prophase of meiosis (Leptotene, Zygotene and Pachytene) takes place in the ovary and it is followed by a diffuse condition of the nucleus. Further stages are initiated only after the penetration of the sperm into the oocyte in the proximal part of the uterus or in the distal part of the oviduct. First and the second polar bodies have a negligible amount of cytoplasm. In some cases division of the first polar body had been observed. The sperm remains in the cytoplasm of the oocyte till the maturation divisions are complete. Later on, both the male and the female pronuclei become vesicular and a fusion between them takes place.

It has been observed that mitotic chromosomes are best studied during spermatogonial divisions and the first cleavage of the zygote. The first cleavage metaphase chromosomes are generally well spread and they give good staining results as contrasted to the spermatogonial metaphase chromosomes. The oogonial divisions are less frequent. Meiotic chromosomes are studied from the maturation divisions of spermatocytes and oocytes.

La Rue (1957) proposed the system of classification of digenetic trematodes based on life cycle studies, larval forms, types of excretory system, its nature of development and other morphological details. Mehra (1957, 1962*a*) accepting the main scheme of classification, proposed some amendmends and some new orders are added. He recognised five orders. *viz.* Echinostomida, Strigeatoidea, Azygatoidea, Hemiuratoidea and Gorgoderida The chromosome numbers of the species are arranged in this scheme of classification (Table II).

Order : Echinostomida

Out of twentyone families of the order Echinostomida in which the chromosome numbers are reported so far, eleven families are represented by a single species each. It is seen that the species with the haploid chromosome numbers of 6, 7, 8, 9, 10, 11, 12, 13 and 14 occur in this order. On the basis of chromosome morphology and number this order is of a diversified nature. In the families Plagiorchiidae and Reniferidae comparatively a large number of species have been worked out for their chromosome number and it is seen that the majority of them have the chromosome number eleven (haploid). Thus, as Britt (1947) pointed out, the families Plagiorchiidae and Reniferidae show close relationship cytologically. In *Encyclometra colubrimurorum* the chromosome number reported by the author is six (haploid) which is low in contrast with the chromosome number of the other species in the family Plagiorchiidae. Moreover, the chromosomes in *E. colubrimurorum* are large in size. On the basis of chromosome morphology and number alone *E. colubrimurorum* may be kept in a separate family.

In the family Paramphistomatidae the chromosome numbers are known in nine species representing six genera. In *Megalodiscus* (*=Diplodiscus*) *temperatus* and *Diplodiscus amphichrus magnus* the chromosome number is eighteen. The morphology of their chromosomes shows much similarity. Comparing the first four pairs of chromosomes it is found that in *M. temperatus* the first pair is sub-metacentric and the rest are metacentric ; while in *D. amphichrus magnus* two of the four pairs are sub-metacentric. *Gigantocotyle bathycotyle* and *Cotylophoron elongatum* are cytologically distinct for having the diploid chromosome number twelve and sixteen respectively. *Zygocotyle lunata* (Willey *et al.* 1951), *Gastrothylax crumenifer* (Dhingra, 1955*b*) and *Paramphistomum crassum* (Srivastava *et al.* 1964*b*) have the same diploid

number (14). The account of the chromosome morphology of these species shows distinct morphological differentiations in the chromosomes. Comparing the first four pairs of chromosomes we find that in *Z. lunata* the first three pairs are acrocentric, J-shaped, while the fourth pair is metacentric ; and in *G. crumenifer* one of the four pairs is acrocentric, J-shaped, while the rest are metacentric. In *P. crassum* the first pair is large, two are small and four are of medium size. The reports on chromosome number of *D. temperatus* by Cary (1909) are not valid as Cort (1915) showed that Cary in his life cycle studies was not dealing with *D. temperatus* but had described two different species of larval trematodes. Cort described them from Cary's material as *Cercaria caryi* and *C. megalura.*

In the family Lecithodendriidae the chromosome numbers of seven species representing seven genera are known. Haploid numbers of 9, 10, 11 and 12 are reported in this family. *Acanthatrium pipistrella* (Britt, 1947), *Loxogenes bicolor* (Britt, 1947) and *Mehraorchis ranarum* have the same chromosome number (11). However, the morphological differentiations of the chromosomes are clear in these species. According to Britt (1947) *L. bicolor* has one long pair, five medium-long and five small pairs and *A. pipistrella* has two long pairs, four medium-long and five small pairs. *Mehraorchis ranarum* has two long pairs, four medium-long and five small pairs, showing similarity with those of *A. pipistrella.* However, the idiogram of the chromosomes of *A pipistrella* constructed by Britt (1947) shows both the long chromosome pairs as sub-metacentric, while in *M. ranarum* the longest pair of the chromosomes is metacentric with equal arms and the second pair is sub-metacentric. The size of the chromosomes is also large in this species. *Brandesia turgidum* (Levy, 1914) and *Pleurogenoides orientalis* have the same chromosome number nine (haploid). In *P. orientalis* there are two pairs of long, metacentric chromosomes. *Ganeo kumaonensis* and *Prosotocus kashabia* are cytologically distinct having the diploid chromosome numbers twenty and twenty-four respectively. The chromosomes of *P. kashabyia* are comparatively small.

In the family Cephalogonimidae Britt (1947) reported fourteen chromosomes (haploid) in *Cephalogonimus americanus,* which is so far the highest number reported in any trematode. In *C. amphiumae* the chromosome number reported by the author is eight (haploid).

In the family Allocreadiidae three species are known for their chromosome number ; two of which have the chromosome number eight (haploid), while the third has twelve (Table II). In the family Bunoderidae *Bunodera luciopercae* has the chromosome number seven and in *B. saculata* has eight. Britt (1947) suggested that *B. saculata* could be an aneuploid species, as in this species out of three long pairs two of the bivalents are so similar that they appear to be duplicates.

Order : Strigeatoidea

Out of six families studied in this order four families are represented by chromosome numbers of a single species. Haploid numbers of 6, 7, 8, 9 and 10 are present in various species in this order.

Order : Azygatoidea

Chromosome number is known in one family in which only two species have been worked out for their cytology. The chromosome number in both is nine (haploid).

Order : Hemiuratioidea

The chromosome numbers are known in six species representing three families in this order (Table II). Haploid numbers of 9, 10 and 11 are present in various

species of this order. In *Genarchopsis singularis* and *G. lobatum* of the family Hemiuridae, have the chromosome number ten. The morphology of the chromosomes is similar in both the species except that in *G. lobatum* the chromosomes are small in size and the first pair shows more chiasma frequency as constrasted to that of *G. singularis*. In the family Halipegidae *Halipegus eccentricus* and *H. mehransis* have the same chromosome number (eleven pairs). In *H. eccentricus* (Guilford, 1962) one large, three medium and seven small pairs are found, while in *H. mehransis* one large, two medium and eight small pairs are present. *H. occidualis* is cytologically distinct having the chromosome number nine. Dhingra (1954*a*) reported haploid chromosome number ten for *Isoparorchis eurytremum* (Family Isoparorchiidae), while Srivastava *et al.* (1964*c*) reported it to be nine.

Order: Gorgoderida

Chromosome number is known in four species (3 genera) representing a single family. Haploid numbers of 6, 7 and 8 occur in this order.

General remarks and conclusion.

On a comparative basis, the chromosomes of the digenetic trematodes show a considerable variation in size. The largest chromosome pair studied in one species of the family Lecithodendriidae measures upto 9·5 micra in length, while the chromosomes in the other species of the same family (e.g. *Prosotocus kashabia*) range from 0·5 to 2·0 micra in length. Britt (1947) reported the large chromosomes

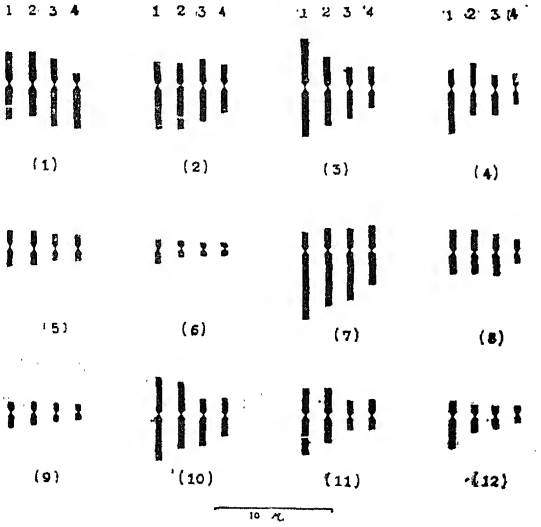

Fig. 40.

Fig. 40. Idiogramms of first four pairs of chromosomes.
(1) *Diplodiscus amphichrus magnus*
(2) *Paradistomum orientalis*
(3) *Mehraorchis ranarum*
(4) *Ganeo kumaonensis*
(5) *Pleurogenoides orientalis*
(6) *Prosotocus kashabia*
(7) *Encyclometra colubrimurorum*
(8) *Cephalogonimus amphiumae*
(9) *Proalarioides tropidonotis*
(10) *Gogatea serpentium*
(11) *Genarchopsis singularis*
(12) *Halipegus mehransis*

in the family Allocreadiidae and the smaller chromosomes in the families Clinostomatidae and Plagiorchiidae. The present study shows that the families Lepocreadiidae, Proterodiplostomatidae and some species of the family Lecithodendriidae also have small chromosomes. *Mehraorchis ranarum* (Lecithodendriidae), *Gogatea serpentium* (Cyathocotylidae) *Encyclometra colubrimurorum* (Plagiorchiidae) and *Paradistomum orientalis* (Dicrocoeliidae) have long chromosome pairs (7·5–9·5 micra in length). At present the cytological data of different species under a family is of a diversified nature, and it does not throw much light over the taxonomy of the group.

As regards the evolution of chromosome numbers in the hermaphrodite animals there are two views :

Muller (1925) maintains that polyploidy should ordinarily be confined to such groups where hermaphroditism is found or where parthenogenetic or vegetative reproduction occurs. Since higher animals are unisexual polyploidy is a rare phenomenon in such animals. Earlier White (1940) suggested that, as the sex chromosome mechanism is not involved in the reproduction of hermaphroditic animals polyploidy could be one of the methods of speciation in such groups of animals. Later, however, While (1954) could not give many evidences in support of this theory and the reports are, therefore, somewhat conflicting.

The other view is that the evolution of chromosome number has taken place by aneuploidy (Britt, 1947).

As per observations on the chromosomes by the author in the present study it is apparent that polyploidy has not occurred in this group. The different species of naturally arranged systamatic groups have chromosome numbers which increase progressively and not by multiples. It is admitted that the present study is confined only to a limited number of species and, therefore, no categorical statement can be made in denying the polyploid origin of species in trematodes. It seems more likely that evolution of chromosome number has taken place by aneuploidy in this group. The present author supports the conclusion of Britt (1947) that there is no evidence of polyploidy within the group digenea and that variations in the chromosome number is due to the gradual addition or loss of the chromosomes.

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Nutritional studies on two species of *Curvularia* causing leaf spot diseases. I. Utilization of various sources of phosphorus

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Introduction

Phosphorus is an essential element as it plays an important part in fungal metabolism. Definite compounds containing phosphorus have been isolated from fungi. It enters into the composition of nucleotides, nucleic acids, phospholipids and other metabolic intermediaries. Phosphorus compounds have a vital role in the functions of chemical transformations and energy transfer (Lilly and Barnett, 1951). According to Cockefair (1931) sugars can not be oxidized without the intervention of phosphorus and nitrates can not be reduced in the absence of its adequate supply. Cochrane (1958) observed that phosphate deficiencies cause several metabolic disturbances, the most easily noticed is lowered rate of glucose utilization.

There are may conflicting report in the literature about the comparative superiority of one phosphorus source over another for different organisms. A substance which supports good growth of a particular fungus may not necessarily induce excellent or satisfactory sporulation of the same, and *vice versa*. It is, therefore, always desirable to study the relative importance of various sources of phosphorus on growth and reproduction of fungi.

Materials and Methods

The cultures employed in the present studies were of *Curvularia ovoidea* (Hiroe and Wantanabe) Muntanola and *Curvularia lunata* (Wakker) Boedijn var. *aeria* (Batista, Lima and Vasconcelos) M. B. Ellis isolated from the diseased leaves of chilli (*Capsicum annum* L.) and Mango (*Mangifera indica* L.), respectively. Asthana and Hawker's medium 'A' (containing 5g. glucose, 3·5g.KNO_3, 1·75g.KH_2PO_4, 0·75g.$MgSO_4.7H_2O$ and 1 litre distilled water) was used as the basal medium. The different sources of phosphorus were singly substituted to supply the same quantity of phosphorus which was present in the basal medium. A medium lacking phospho us was also prepared. The pH of the media was always adjusted to 5·5 as it was found to be most suitable for the growth and sporulation of the organisms (Singh, 1968). The degree of sporulation is based on the average number of spores present in the low power field of microscope and it is divided in the following categories :

No Spore	..	Absent
1–10 Spores	..	Poor
11–20 Spores	..	Fair
21–30 Spores	..	Good
Above 30 Spores	..	Excellent

Statistical analysis of the data has been carried out separately for each species.

Observations

The average dry weight of mycelium, sporulation and final pH of the media supporting growth of the two species are recorded in Table 1 and 2.

TABLE 1

Showing dry weight of mycelium, sporulation and final pH of the media supporting growth of C. ovoidea

Phosphorus sources	Dry weight in mg.	Sporulation	Final pH
1. Potassium dihydrogen phosphate	98·9	Excellent	6·7
2. Dipotassium orthophosphate	45·7	Excellent	7·3
3. Magnesium phosphate	66·3	Fair	7·0
4. Sodium dihydrogen phosphate	53·9	Excellent	6·9
5. Sodium dibasic phosphhte	55·6	Fair	6·8
6 Ammonium phosphate	43·1	Absent	2·8
7. Calcium phosphate	48·7	Fair	5·8
8. No phosphorus	36·7	Fair	6·0

Average = 56·1

Summary and conclusions at 5% level of Probability are given below :

Treatments	. . Highly significant
Replicates	. . Non-significant
Standard error	. . 2·20
Critical difference	. . ± 6·40

Dry weight results :

1 > 3 > 5 4 7 2 6 8

TABLE 2

Showing dry weight of mycelium, sporulation and final pH of the media supporting growth of C. lunata *var.* aeria.

Phosphorous sources	Dry weight in mg.	Sporulation	Final pH
1. Potassium dihydrogen phosphate	64·6	Excellent	7·0
2. Dipotassium orthophosphate	54·1	Good	7·0
3. Magnesium phosphate	55·4	Good	7·1
4. Sodium dihydrogen phosphate	56·9	Excellent	6·8
5. Sodium dibasic phosphate	30·8	Excellent	7·0
6. Ammonium phosphate	37·8	Poor	3·4
7. Calcium phosphate	37·9	Excellent	6·0
8. No phosphorus	22·9	Fair	6·8

Average = 45·0

Summary and conclusions at 5% level of Probability are given below :

Treatments	. . Highly significant
Replicates	. . Non-significant
Standard error	. . 2·04
Critical difference	. . ± 5·80

Dry weight results :

1 > 4 3 2 > 7 6 > 5 > 8

It is evident from Tables 1 and 2 that all the sources of phosphorus were not of equal importance for the organisms under study. Potassium dihydrogen phosphate supported the best growth of both the pathogens. Their growth was good on magnesium phosphate. The mycelial output of *C. lunata* var. *aeria* was good on dipotassium orthophosphate and sodium dihydrogen phosphate whereas they supported poor and moderate growth respectively of *C. ovoidea*. The dry weight yield of *C. ovoidea* and *C. lunata* var. *aeria* was moderate and poor, respectively, on sodium dibasic phosphate. Both the organisms attained only poor growth on ammonium phosphate and calcium phosphate. The medium deviod of phosphorus induced only poor mycelial development of the two pathogens.

Potassium dihydrogen phosphate and sodium dihydrogen phosphate supported excellent sporulation of both the organisms. The sporulation of *C. ovoidea* was also excellent on dipotassium orthophosphate which induced good spore development of the other organism. *C. lunata* var. *aeria* attained excellent sporulation on sodium dibasic phosphate and calcium phosphate which supported fair sporulation of *C. ovoidea*. The sporulation of *C. ovoidea* was fair on magnesium phosphate while *C. lunata* var. *aeria* showed good spore production. Ammonium phosphate, which did not induce spore formation of *C. ovoidea*, supported poor sporulation of *C. lunata* var. *aeria*. Both the pathogens showed fair sporulation on the medium lacking phosphorus.

Due to growth of the organisms the pH of the media increased in all the cases, except when ammonium phosphate was the source of phosphorus. The fall in pH may be due to preferential utilization of cations resulting in the increased acidity of the media. According to Cochrane (1958), "The pH is affected during growth by metabolic activities—raised by absorption of anions or production of ammonia from nitrogenous compounds, lowered by formation of organic acids or absorption of cations".

Discussion

Potassium dihydrogen phosphate, which was a good source for the organisms under study has also been reported to yield good growth of mango and guava isolates of *Alternaria tenuis* (Singh and Tandon, 1967) and *Colletotrichum gloeosporioides* (Tandon and Verma, 1962) Bhargava and Tandon (1963) obtained good growth of *Fusarium solani*, *Macrophomina phaseoli* and *Botryodiplodia ananassae* on dipotassium orthophosphate. In this respect *C. lunata* var. *aeria* was similar to the organisms studied by them. The growth of *C. ovoidea* was poor and it differed from them. The moderate growth of *C. ovoidea* on sodium dihydrogen phosphate was similar to that of *Colletotrichum gloeosporioides* (isolate C) studied by Lal (1967) but differed from *C. lunata* var. *aeria* and isolates F and G of *C. capsici* which attained good growth. Sodium dibasic phosphate supported moderate growth of *C. ovoidea* and poor of *C. lunata* var. *aeria*. In this respect they differed from the two species of *Colletotrichum* (Lal, *l.c.*) which attained good growth. The organisms under study were similar to *Fusarium solani* and *Botryodiplodia ananassae* (Bhargava and Tandon, 1963) as they also showed good growth on magnesium phosphate. The growth of the present organisms was poor on ammonium phosphate and was similar to that of *Botryodiplodia ananassae* (Bhargava and Tandon, *l.c.*) and five isolates of *Colletotrichum gloeosporioides* (Lal, 1967). The poor growth of the organisms under study on calcium phosphate differed from that of the two species of *Colletotrichum* (Lal, *l.c.*) which attained good growth on it. Both the fungi under study could grow in the absence of phosphorus but the growth was poor and in this respect they were similar to *Curvularia lunata* (Srivastava, 1951), *Curvularia penniseti* and *Fusarium coeruleum* (Agarwal, 1955), *Pestalotia* sp. (Tandon and Bhargava, 1960) and

Colletotrichum gloeosporioides (Tandon and Verma, 1962). They, however, differed from *Phytophthora* spp. (Mehrotra, 1949) which failed to grow on the medium lacking phosphorus.

Summary

Phosphorus requirements of *Curvularia ovoidea* (Hiroe and Wantanabe) Muntanola and *Curvularia lunata* (Wakker) Boedijn var. *aeria* (Batista, Lima and Vasconcelos) M. B. Ellis isolated from the diseased leaves of chilli (*Capsicum annum* L.) and mango (*Mangifera indica* L.) respectively were investigated. The growth of *C. ovoidea* was good on potassium dihydrogen phosphate and magnesium phosphate; moderate on sodium dihydrogen phosphate and sodium dibasic phosphate. It was poor on the remaining sources as well as on phosphorus free medium. The mycelial yield of *C. lunata* var. *aeria* was good on potassium dihydrogen phosphate, dipotassium orthophosphate, magnesium phosphate and sodium dihydrogen phosphate; and poor on the rest including the medium devoid of phosphorus. The degree of sporulation of the organisms on various sources of phosphorus and changes in the pH of media have also been recorded.

Acknowledgements

The authors are thankful to the Head of the Botany Department for laboratory facilities, to C. S. I. R. for financial assistance to R. N. T., and to the Ministry of Education, Government of India for the award of S. R. T. scholarship to B. P. S.

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Additions to Penicillia of India—I

By

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[Received on 8th March, 1968]

Introduction

Out of nearly 141 species of the genus *Penicillium* known (Raper and Thom, 1949) only about 55 have been reported from India of which 12 were from this laboratory. Several isolations of Penicillia from a variety of substrates have been made recently. Six of the species, not yet reported, are being described here.

Descriptions of the isolates

Penicillium canescens Sopp, in Monogr. pp. 181–182, Taf. XIX, fig. 136; Taf. XXIII, fig. 28. 1912.

Colonies on Czapek's solution agar growing restrictedly, consisting of a tough basal mycelial felt overgrown by loose network of vegetative hyphae, plane or slightly radially furrowed, white when young quickly changing to greyish-green with the development of conidial structures, colony margin thin and white; odour not very much pronounced but appearing somewhat mouldy; reverse of the colony yellowish, changing to brownish shades in age; conidiophores arising from the substratum as well as from the aerial hyphae, conspicuously roughened (warted), varying in size, ranging from 20 to 350μ in length; penicilli asymmetrically biverticillate, strongly divaricate, variable in size and complexity; branches variously arranged, occasionally rebranched, strongly divergent, 10–25μ by 2·5–3·0μ, slightly roughened; metulae 2 to 4, 8·0–20μ by 2·5–3·0μ, slightly roughened; sterigmata in groups of 4 to 8, 8·0–9·0μ by 2·0–2·8μ, with short conidia bearing tubes; conidia globose to subglobose, with walls delicately roughened, mostly 3·0μ but ranging from 2·5–3·0μ, forming loose columns, 50–60μ long.

Colonies on malt-agar growing at the same rate as on Czapek, but the appearance of the colony is somewhat floccose, sporulating more abundantly, penicilli and spores same as on Czapek.

Description based on a culture No. Px–72 isolated from soil, pH 6·1 of Gorakhpur. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

This isolate resembles with the type description given by Raper and Thom (1949) except for the fact that conidiophores are smaller, conidia are slightly larger, and the exudate is absent.

Penicillium corymbiferum Westling, in Arkiv for Botanik **11** : 56, 92–95; figs. 16, 58. 1911.

Colonies on Czapek's solution agar growing rapidly, deep in the centre of the colony, distinctly zonate near colony margin, surface appearing granular with definite fascicles easily viewed at colony marginal areas, colony margin white

changing to greenish shades, heavily sporing throughout ; conidial areas yellowish brown becoming slate olive in age ; exudate abundantly produced in the form of yellowish droplets leaving distinct craters after evaporation ; odour mouldy; reverse of the colony dull yellowish ; conidiophores arising mostly from the substratum, variable in length, mostly 150–300μ in the colony marginal areas and 500–1000μ in the strongly fasciculate colony central areas, 3·5–5·0μ in diameter, coarsly roughened ; conidiophores comprising the coremium tending to diverge and often terminating as feathery mass of conidial structures ; penicilli asymmetrically branched, mostly 35–50μ in length, consisting of one appressed branch in addition to main axis ; branches 16–30μ by 3·5–4·5μ with surface somewhat roughened ; metulae slightly enlarged at the apex, finely roughened, in groups of 3 to 5, 12–20μ by 3·0–4·0μ; sterigmata in clusters of 4 to 7 on each metulae, smooth walled, 8·0–12·0μ by 2·5–3·0μ ; conidia globose to subglobose, smooth walled 3·0–3·8μ in diameter, forming tangled chains, 40–100μ in length.

Colonies on malt-agar growing comparatively more rapidly, plane with floccose overgrowth in the extreme centre, penicilli as on Czapek but conidiophores and branches are more coarsely roughened.

Description based on culture No. Px–73 obtained from the rotten fruit of *Phyllanthus emblica*. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

This isolate closely agrees with the type description of *P. corymbiferum* Westling except for the fact that it produces abundant exudate in the form of yellowish droplets on Czapek's medium which leaves distinct craters after evaporation. This character was not reported earlier.

Penicillium cylindrosporum Smith, in Brit. Mycol. Soc. Trans. **40**(4) : 481–488, 1957.

Colonies on Czapek's solution agar growing restrictedly, thin, velvety, plane, heavily sporing throughout, white when young, changing from dull avellaneous to pale smoke grey (R. Pl. XLVI) on maturity ; exudate in the form of minute droplets restricted to the centre of the colony, yellowish brown in colour ; reverse colourless to dirty brown ; conidiophores often arising from the submerged mycelium, occasionally from the aerial hyphae, long, wall roughened ; penicilli asymmetrically biverticillate, irregularly one or twice branched ; metulae commonly arising at different levels of penicillus, in groups of 2 to 4, 8–13μ by 2·2 to 3·0μ ; sterigmata narrowed at the apex, mostly (5) 9 to 12μ by 2 to 2·5μ ; conidia short cylindrical, occasionally ovate to ellipsoidal 3·0–5·5μ by 2·0 to 2·5μ, smooth walled ; conidial chains divergent then tangled or sometimes in several loose, twisted columnar masses.

Colonies on malt-agar growing somewhat more rapidly, plane and heavy sporing ; penicilli duplicating the measurements on Czapek's conidia also the same.

Description based on an isolate No. Px–74 obtained from soil of Lohgarha (Shankergarh). Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

This isolate resembles in most respects with the type description given by Smith (1957). However, the only difference is that the sterigmata are not all of the same size (11 × 2·5μ) as reported by Smith. The exudate is yellowish brown in colour instead of green as reported by Smith (1957).

Penicillium jensenii Zaleski, in Bul. Acad. Polonaise Sci. : Math. et. Nat. Ser. B, pp. 494–495, Taf. 57. 1927.

Colonies on Czapek's solution agar growing restrictedly, loose textured, somewhat lanose, colony margin thin, white, central area somewha traised, folded

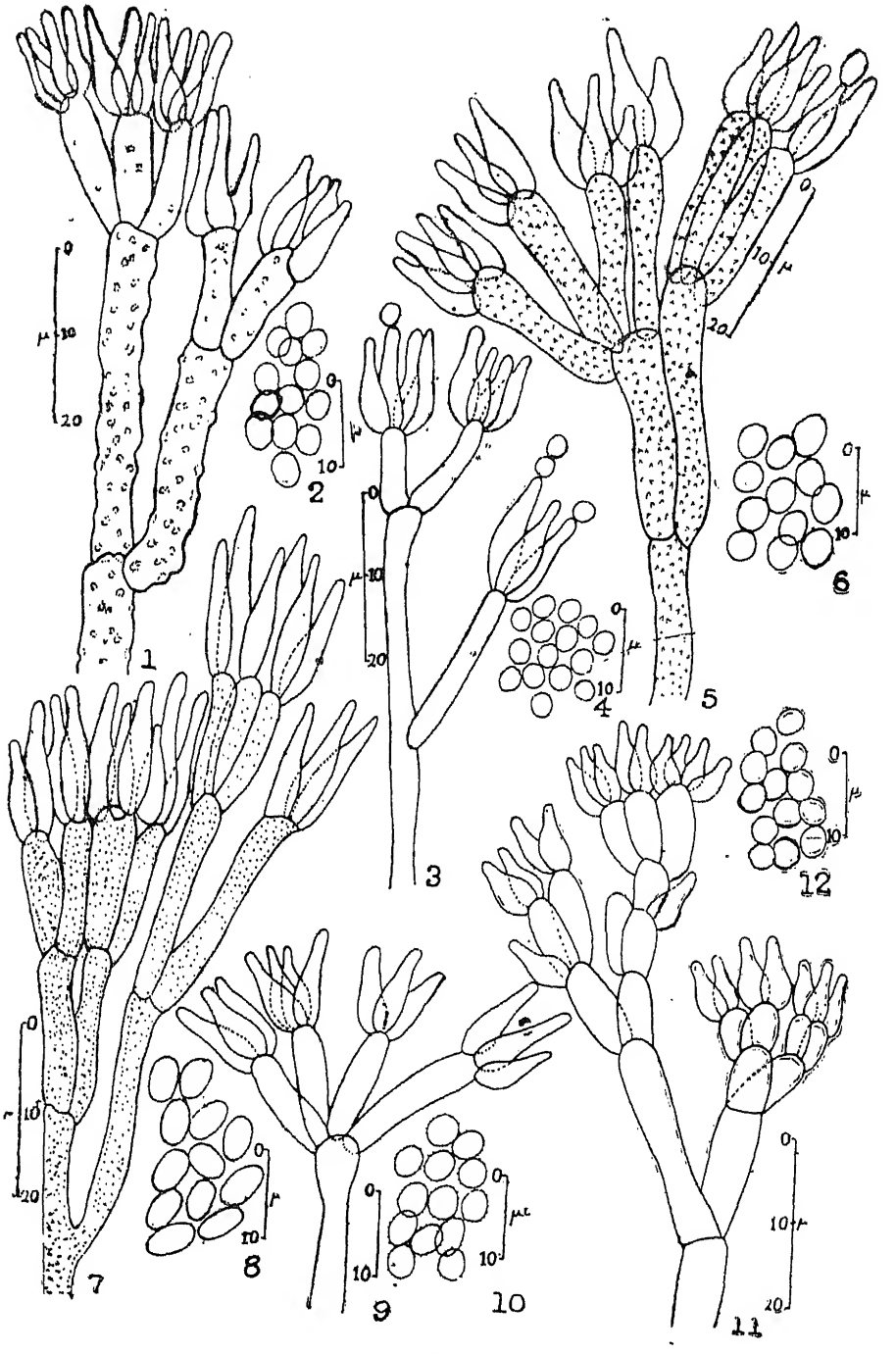

PLATE I

Fig. 1-2, *P. canescens* Sopp, 1, detailed drawing of penicillus : 2, Conidia (delicately roughened).

Fig. 3-4, *P. jensenii* Zaleski, 3, detailed drawing of a single penicillus showing asymmetrically divaricate and monoverticillate structures : 4, conidia.

Fig. 5-6, *P. corymbiferum* Westling, 5, detailed drawing of a single penicillus showing roughened conidiophore, branches and metulae, : 6, few conidia.

Fig. 7-8, *P. cylindrosporum* Smith, 7, detailed drawing of a single penicillus (twice branched): 8, cylindrical conidia.

Fig. 9-10, *P. pulvillorum* Turfitt, 9, detailed drawing of a single penicillus showing roughened conidiophore and constricted sterigmata. 10, conspicuously roughened conidia.

Fig. 11-12, *P. urticae* Bainier, 11, detailed drawing of a penicillus 12. Conidia.

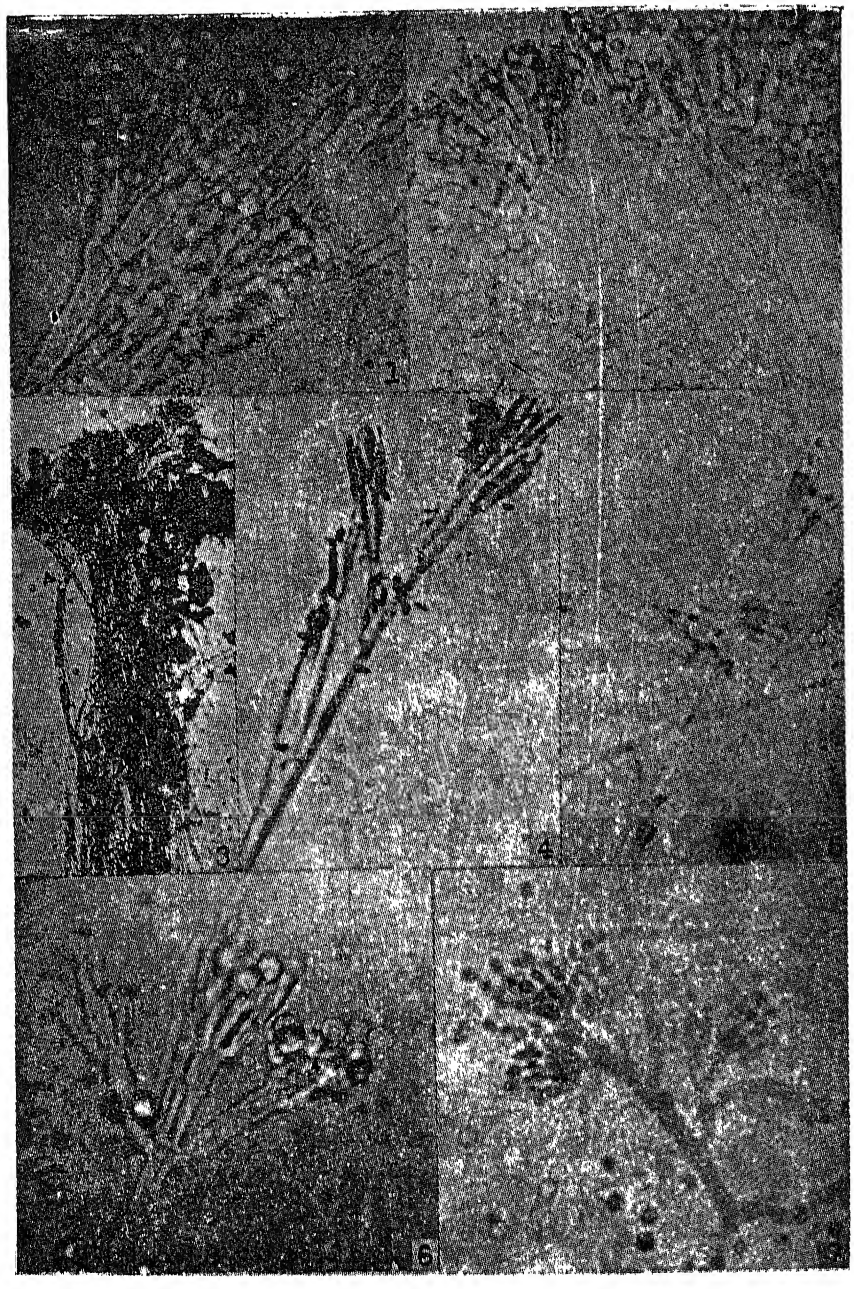

PLATE II

Fig. 1. *Penicillium canescens* Sopp, details of a single penicillus and roughening of conidiophores and metulae × 1000.
Fig. 2–3. *Penicillium corymbiferum* Westling, 2, details of penicillus × 800, 3, feather like structure formed due to fasciculation of conidic phores. × 40.
Fig 4. *Penicillium cylindrosporum* Smith, details of a single penicillus × 920.
Fig. 5. *Penicillium jensenii* Zaleski, details of penicilli × 850.
Fig. 6. *Penicillium pulvillorum* Turfitt, details of a single penicillus, and roughening of conidia, × 1350.
Fig. 7. *Penicillium urticae* Bainier, details of penicilli × 850.

and wrinkled, white when young changing to greyish green shades, heavily sporing throughout ; exudate not pronounced ; odour lacking ; colony reverse uncoloured ; conidiophores variable, smooth, arising directly from the substratum and also as lateral branches from the trailing hyphae, ranging from 125–450μ by 2·0–2·5μ ; penicilli strongly divaricate, usually asymmetrically branched, but often monoverticillate structures are also observed ; metulae 2 to 3, 9·0 to 13·0μ by 1·5 to 2·5μ ; sterigmata in groups of 5 to 7, with well defined conidia bearing tubes, 6·5 to 7·5μ by 1·8–2·0μ ; conidia globose to subglobose, smooth ranging from 2·0 to 2·5μ, forming chains which tend to adhere into loose columns.

Colonies on malt-agar growing slightly more rapidly in comparison to Czapek, plane, appearing lanose, penicilli and conidia same as on Czapek.

Description based on a culture No. Px-75 isolated from soil, pH 7·0 of Delhi. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

This isolate closely agrees with the description of *P. jensenii*, as given by Raper and Thom (1949), in "A Manual of the Penicillia", except in having slightly smaller conidiophores.

Penicillium pulvillorum Turfitt, in Brit. Myc. Soc. Trans. **23** : 186-187, Pl. IV, figs. 1 and 2. 1939.

Colonies on Czapek's solution agar growing restrictedly, matted floccose, at first white to pale green, becoming deeper green gradually turning brownish from centre outwards with the development of sclerotia, with abrupt white margin, showing radial furrows in old colonies ; odour not distinguishable ; exudate lacking ; reverse colourless when young changes to deep brownish shades ; conidiophores arising from the trailing hyphae, roughened, 115-275μ in length by 3–3·7μ in diameter ; penicilli large, asymmetric divaricate, monoverticillate structures are also not uncommon ; metulae in groups of 2 to 5, 12·0–18·0μ by 3·0–3·8μ ; sterigmata constricted at the tip, 3 to 6 on each metula, 7·5-9·0μ by 2·5-3·2μ ; conidia globose, conspicuously roughened, 3·0-3·5μ in diameter, forming divergent chains, which become tangled in age ; sclerotia produced after one week, abundant, pinkish brown, very irregular in shape, measuring about 90-225μ in diameter, consisting of compact hyphal masses, remaining soft.

Colonies on malt-agar somewhat spreading, plane, appearing floccose, thin, penicilli and conidia duplicating the measurements on Czapek's sclerotia produced more abundantly, forming clear zones.

Description based on a culture No. Px–52, isolated from the soil of Lohgarha. Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

The isolate differs from the type description, in having roughened conidia on Czapek's medium and smaller sclerotia. However, Raper and Thom have found slightly roughened conidia in malt-agar.

Penicillium urticae Bainier, in Bul. Soc. Mycol. France, **23** : 15–16, Pl. IV, figs. 1–5. 1906 ; *ibid.* **23** : Pl. V, figs. 10–16. 1907.

Colonies on Czapek's solution agar growing restrictedly, plane, sometimes with very faint radial furrows, azonate, surface appearing mealy, simple conidiophores and fascicles intermixed but fascicles prominent predominating in colony marginal areas, centre of colony somewhat raised with abrupt white margin, heavily sporing throughout ; colour of colony light blue-green changing to greyish green shades in age ; exudate abundantly produced in the form of

colourless droplets ; reverse of the colony white changing to dull yellowish shades at maturity ; conidiophores in the central colony areas simple and in fascicles but in marginal areas mostly in fascicles, smooth walled, ranging from 200–450μ by 3·0–3·5μ, penicilli typically asymmetrical, biverticillate, large, divergent, variously branched, mostly 40–75μ in length, but sometimes reaching upto 90μ ; branches divergent, secondary branches also common, primary branches usually 13–40μ by 3·0-3·8μ, secondary branches 7·5–15μ by 2·8 to 3·8μ arising at different levels in the penicillus, metulae and secondary branches often poorly differentiated ; metulae in groups of 2 to 4, rarely more, 7·5–10μ by 3·0–3·5μ ; sterigmata crowded, small, usually 4 to 5 in a verticil, 5·0–6·0μ, by 2·0–3·0μ without having any conidia bearing tube ; conidia globose to subglobose, 3·0–4·5μ by 2·8-3·8μ, smooth walled, forming divergent conidial chains ranging from 50–90μ or more.

Colonies on malt-agar growing restrictedly as on Czapek's medium but appearing plane, penicilli and conidia same as on Czapek's.

Description based on a culture No. Px-76 isolated from soil of Rewa (M.P.). Culture deposited in BSM Culture Collection, Botany Department, University of Allahabad.

This isolate resembles much with the description of *P. urticae* as given by Raper and Thom (1949). The only difference is that the primary branches are longer and the conidia are slightly larger and they are globose to subglobose instead of elliptical.

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Studies on *Argemone mexicana* Linn.—IV. Phenology, dispersal and stomata

By

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Studies on the biological equipment of *Argemone mexicana* has revealed facts of interest and importance. The plant occurs in open on dry nitrogen poor soils and in shade on moist nitrogen rich soils (Kaul, 1965). It was found that the growth performance of the plant differs considerably in the two habitats (Kaul, 1967*a*). The present study was undertaken to evaluate the effects of these two habitats upon phenology, dispersal and stomatal apparatus, of the plant.

Phenology : The phenological observations of *A. mexicana* are given in Table I. From the table it is apparent that plants of *A. mexicana* growing in the shade accomplish floration and fruiting later and last longer than those growing in open. In both the habitats, the maturation and ripening of seeds are accomplished within 1–2 months inside the drying capsules. While seed dissimination of open growing plants continues upto early June, in shade plants it continues till mid July.

TABLE I

Phenological observations of Argemone mexicana at Varanasi (U.P.) and its outskirts in open (A) and in shade (B).

Months in which	A	B
Seed germinates	Early December	Early December
Leaf growth begins	Middle December	Mid December
Leaves attain full size	January	Late January
Elongation of shoot ceases	Middle February	March
Floral buds appear	Early January to late March	Feb.–March
First bloom	January to March	Mid Feb.–March
Bloom over	Early April	Late April
Fruiting starts	Middle January to Middle April	Late March to May
Seeds ripen	Early February to late April	April to late May
Seed dissemination begins	March to May	April to late June
Seed dissemination complete	Early June	Mid July
Leaves begin to fall off	May to June	Mid July
All leaves have fallen	Late June	Late July

Dispersal : The wide range of habitats and geographical areas occupied by *A. mexicana* (Kaul, 1965, 1966), call for an examination of modes of its dispersal.

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The mode of dispersal of the plant in both the habitats is more or less similar and is as follows :

Wind Dispersal : The fruit at maturity opens by pores immediately beneath the stigmatic disk (Fig. 1-3). The stalk of the mature capsule becomes stiff. It alternatively bends and recoils or springs back with the gusts of wind or when jolted by the passing animals and jerks the seeds out. The distance to which the seeds are jerked out depends mainly upon the wind action and height of the capsule above the ground level (Table II ; Fig. 4). The slinging of the seeds out of the capsule through the pores is like a 'Censor mechanism' ; for it allows only a limited number of the seeds out of the capsule at a time. The emergence of the seeds out of the capsule in this manner is known as 'Jactitation'.

The effectiveness of wind dispersal was studied in May, 1964. Circles with radii of 25, 50, 75, 100, 125, 150, 175, and 200 cm. were drawn on the ground. One potted plant each of *A. mexicana* was placed in the centre for three successive days. Single ripe capsule of the experimental plant was left and the rest were clipped off. The number of seeds dropped at various distances in 12 hours, *i.e.* from 7 A.M. to 7 P.M. were recorded. The results have been set in Table II and Fig. 4. It is evident from the table, that the seeds of *A. mexicana* are not dispersed too far off from the parent plant by the direct action of wind. However, wind dispersal is less potent in the plants growing in shade than in that of the plants growing in open because the shade growing plants being protected do not get subjected to direct wind action unlike open growing plants.

Water Dispersal : The seeds of *A. mexicana* are covered by a thin coat of wax which inhibits an immediate absorption of the water. The shallow pits in the seed coat appear to act as air pockets (Kaul, 1967*b*). These add to its buoyancy. Also the seeds float in water for 1-3 days or even more as found presently. This would probably lead to the carrying off of the seeds to some distances by water currents, especially during the rainy season, when the soil (where the plants had grown earlier) is loaded with the seeds.

Animal Dispersal: Rats were found taking the seeds of *A. mexicana* to their holes. While carrying the seeds, a few fall on the way. These germinate at the onset of favourable conditions. Hence, the occurrence of *A. mexicana* in the crevices and wall holes as reported earlier (Kaul, 1967) may be due to dispersal by rats.

TABLE II

Seed dispersal of A. mexicana

Plant No.	Height of the plant from floor (cm)	Height of the capsule from floor (cm)	Seeds dispersed (%)	Seeds left in the capsule (%)	Frequency of seeds dispersed in between							
					0–25 (cm)	25–50 (cm)	50–75 (cm)	75–100 (cm)	100–125 (cm)	125–150 (cm)	150–175 (cm)	175–200 (cm)
1.	56	54	39	61	25	41	23	7	2	2	–	–
2.	58	55	37	63	19	44	27	5	2	1	2	–
3.	63	61	44	56	16	51	18	6	4	2	1	2

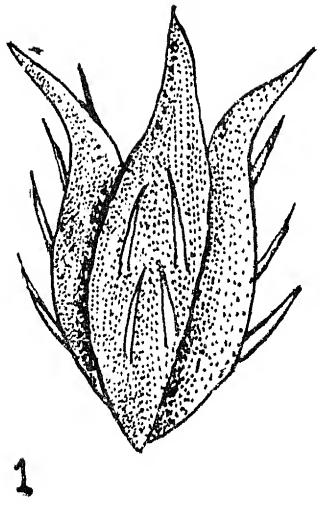


Fig. 1. Young flower bud of *Argemone mexicana*.

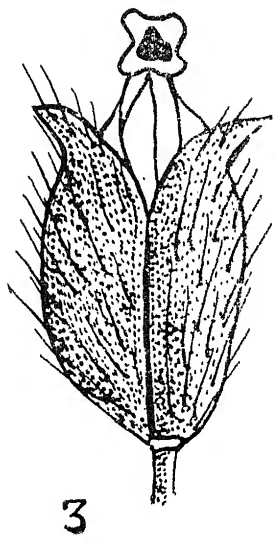
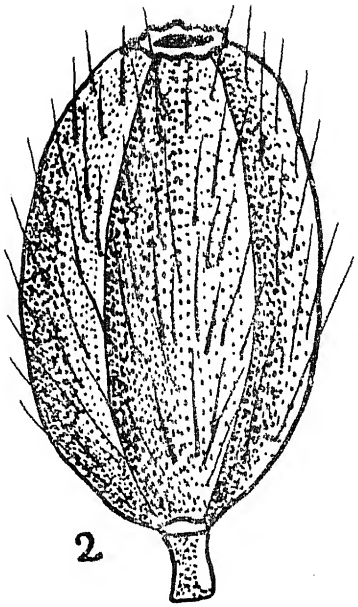


Fig. 3. Dehisced friut of *A. mexicana*.



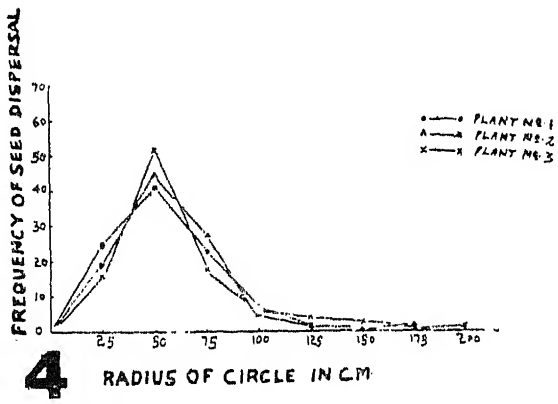
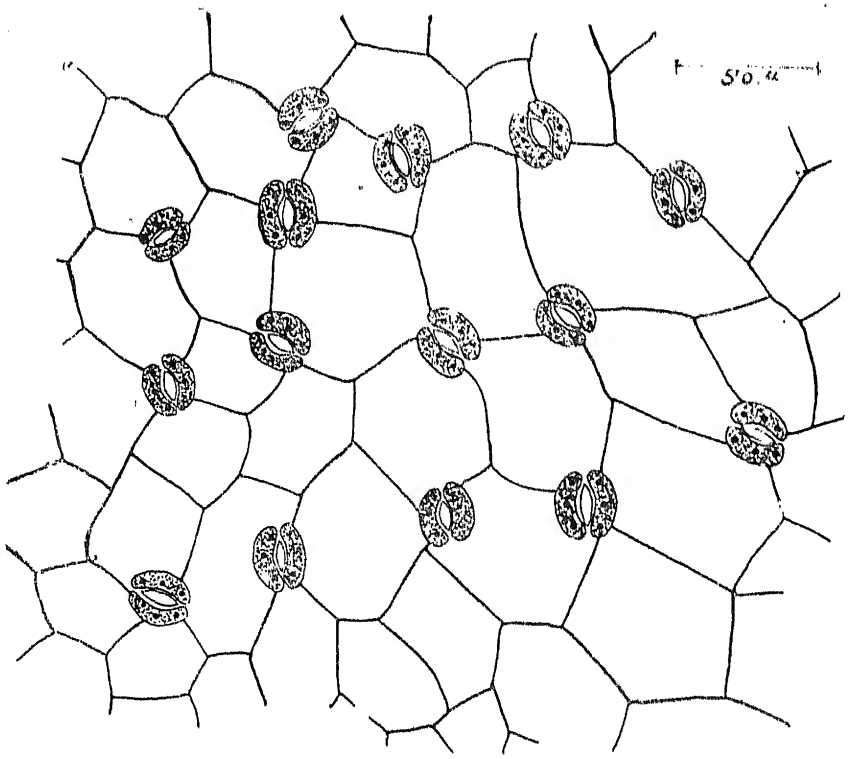
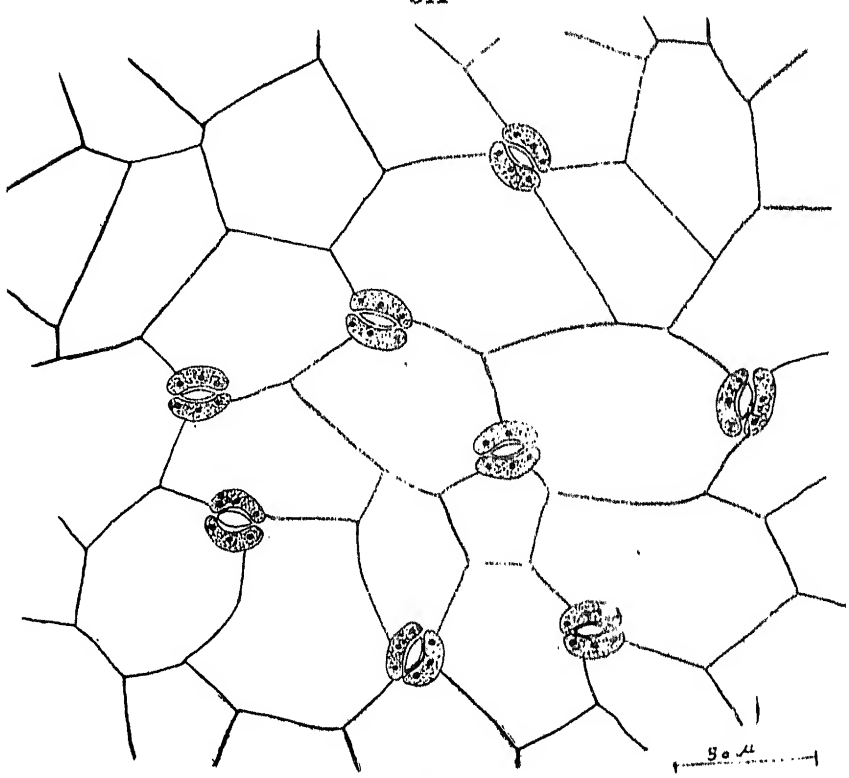


Fig. 2. Mature undehisced fruit of *A. mexicana*.

Fig. 4. Frequency of seed dispersal by wind of three *A. mexicana* plant (1–3).



5A



5B

Fig. 5. Stomata of open (A) and partial shade. (B) leaves of *A. mexicana*.

Bird Dispersal : Holomboe (*See* Ridley, 1930) recorded that the bird *Pincola enucleator* eats away the seeds of *A. mexicana* most frequently, and passes them out in the excreta unharmed. Gabrielson (1924) from America reported that many winter birds eat away the seeds of the plant. Since movement of birds is quick and migration very common, they also seem to aid in dispersal and dissemination of *A. mexicana.*

Ant Dispersal : An interesting method of dispersal in *A. mexicana* is by ants. The seed coat contains a little oil which serves food for the ants. Hence, ants carry the seeds to their dwellings located usually in cultivated fields, ornamental gardens, lawns, etc. These were found filled with the seeds of *A. mexicana* by the present worker. Since the ants cherish oil only, the seeds remain unharmed. These seeds on collection germinated normally. The method of dispersal by ants may explain to a little extent the frequent occurrence and persistance of *A. mexicana* in the places where ants live.

Bews (1918) regarded the ants to play an important role in spread and dissemination of *A. mexicana*, in South Africa. Hence. transport of seeds by ants, that is not of courses to a great distance, seems to add to the diffusion of the plant to some extent.

Stomata : There appears to be no difference in structure and shape of stomata of *A. mexicana* in both the habitat plants. The leaves are amphistomatal and the stomata are of anomocytic (Ranunculus) type. The epidermal cells of both the leaf surfaces are straight in outline, and these cells though isodiametric are intercalated by somewhat bigger cells also (Fig. 5). The stomata appear at a slightly lower in the upper and in general level of the epidermal cells on the lower surface in a transection. They are scattered irregularly and have their long axes extending in various directions (Fig. 5). The data regarding stomatal index and frequency on the dorsal and ventral surface of the leaves are presented in Table III.

As is apparent from the table, the stomatal frequency and index are higher on dorsal surface than on the ventral surface of the leaves, in both the habitat plants. A decreasing gradient of these from appex to the base was observed in the fully developed leaves (Table, III). But no such gradient from the mid rib to the margin of the leaf was observed. Both the stomatal index and frequency are higher under exposed than under partial shady habitats. The maximum stomatal pore dimension is $16{\cdot}64\mu \times 8{\cdot}32\mu$ on an average in both the habitats.

Discussion

While, both, vegetative and reproductive growth in *A. mexicana* is completed during winter months at Varanasi, the seed dissemination continues from March to early June in the plants growing in dry and exposed areas and from April to July in those growing in moist and shady places. In fact, shade growing plants accomplish floration and fruiting latter and last longer in the field in nature at Varanasi and its out skirts than those growing in dry and exposed areas. However, a slight drift in environmental rhythm deviates accordingly, the sequential phases of its life cycle ; or otherwise, the seed germination, seedling growth, and vegetative and reproductive flush seem to be well correlated with the environmental rhythm (Kaul, 1965). Hence, the plant though possesses a precise and dependable method of time measurement, requires a continuous information from the environment, and resembles in this behaviour to other plants studied by the author (Kaul, 1965).

TABLE III

Stomatal study of A. mexicans

(Mean values of 45 leaves of the second node, per site)

Habitat	Site No.	Frequency						Index					
		Dorsal surface			Ventral surface			Drosal surface			Ventral surface		
		Tip	Middle	Base	Tip	Middle	Base	Tip	Middle	Base	Tip	Middle	Base
Dry and exposed	I	208±3	163±7	102±6	197±4	132±3	107±6	31·9±0·2	26·8±0·7	25·8±0·3	28·4±0·2	23·6±0·1	21·6±0·4
	II	213±4	184±3	109±3	203±5	137±2	113±4	32·2±0·3	26·8±0·3	25·1±0·5	27·8±0·6	23·4±0·3	22·1±0·7
	III	219±7	176±5	121±7	191±2	148±5	126±3	32·4±0·2	27·7±0·1	24·9±0·7	27·6±0·4	23·8±0·4	22·0±2
	Average mean	213	175	110	197	139	115	32·1	27·1	25·3	27·9	23·6	21·9
Partial shady and moist.	I	172±3	93±4	62±7	128±4	72±6	51±4	29·4±0·3	25·8±0·4	19·3±0·6	23·4±0·2	21·2±0·1	18·1±0·4
	II	176±7	98±3	66±4	139±2	81±3	59±2	29·7±0·1	25·2±0·7	19·9±0·8	23·8±0·4	21·9±0·7	18·7±0·2
	III	163±7	104±2	69±6	151±3	97±4	57±8	29·1±0·3	24·9±0·6	20·7±0·3	20·9±0·4	21·9±0·4	18·9±0·7
	Average mean	170	98	62	139	77	59	29·4	25·3	19·9	23·4	21·7	19·6

± indicates standard deviation values

The seeds of *A. mexicana* are dispersed from the capsule by "Jactitation". Such a censor mechanism barely removes all the seeds from the capsule at a time, instead there is a periodic dispersal of a limited number of seeds at a time. In strong winds (common in May at Varanasi) a large number of seeds are thrown off to a considerable distance from the parent plant growing on exposed areas. The seeds are also carried in the sand, soil, gravel and other materials used in the construction of buildings, dams, raods, etc. These seeds also get contaminated with mustard seeds because of their obvious resemblance. Daubenmire (1959) regards the contamination of wild seeds with useful seeds as an important means of dissemination of the former.

The plant is abundantly found growing on mounds, heaps and many other similar elevated areas. The excessive run off of water at these places during the rainy season aids in carrying away the seeds of *A. mexicana* far off from the capsule and/or may blow them into water courses which may carry them as usual. The seeds get deposited in depressions, banks of canal and streams alongwith the eroded soil. In such soils they get a good chance to establish on the alluvium thus deposited. This explains the frequent presence of *A. mexicana* on such places. In low lying areas, drying ponds and other allied temporary water reservoirs, the seeds of *A. mexicana* are carried by flood water. When the flood recedes, the mud flats and sand banks form an admirable nidus for germination of the seeds. This finally culminates in its luxuriant growth on such places. In short one is prone to say that a combination of wind, water, and animal dispersal aids considerably in wide geographical and ecological distribution of *A. mexicana* which really knows no bounds.

The number of stomata per unit area and stomatal index give an idea of water relations of the species in a purely comparative way. In *A. mexicana*, the epidermal structure of the leaf is not much influenced by the prevailing environment (Fig. 5). But the distribution pattern of stomata, their frequency and index are much closely related to the habitat as also to the position of the leaf (Table III). Conditions that tend to reduce leaf size, *e.g.*, deficiency of water and bright light, result in an overcrowding of stomata (Daubenmire, 1959). Hence, in *A. mexicana* there is an increase in stomatal frequency in the leaves of dry and exposed habitat plants (Table III).

There is a significant difference in the stomatal indices between partial shady and moist, and in dry and exposed leaves of *A. mexicana* (Table, III). There is a significant decrease in stomatal indices from tip to base on dorsal and ventral surface in both dry, and exposed, and partial shady and moist habitat leaves of the plant. The presence of stomata at a lower level in the upper and in a general level of the epidermal cells on the lower surface indicate a xerophytic character of *A. mexicana* and this is not influenced by the habitats in which it occurs.

Summary

The phenological observations on *Argemone mexicana*, indicate it as winter annual at Varanasi. But the phenology of the plant is considerably influenced by the habitat. The plants growing in moist shady areas stay longer as well as accomplish vegetative and floral growth more slowly in nature at Varanasi and its outskirt than those growing in exposed and dry areas. The seeds of the plant are dispersed by wind, water and animals. The effectiveness of wind dispersal is experimentally studied. A common occurrence and wide distribution of the plant are correlated with its efficient dispersal mechanism.

The stomatal frequency and index on the dorsal surface are much higher than on the ventral surface in the leaves of both the habitat plants. These values decrease from apex to base. The stomatal frequency is considerably higher in dry and exposed habitat leaves than in the moist and shady habitat leaves.

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Certain Autecological Observations on *Euphorbia dracunculoides* Lamk., a Serious Weed of Cultivation[1]

By

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Introduction

Importance of ecology in weed researches has been stressed by Harper (1958) and Misra (1963). Despite its vital role, ecology of weeds has not been intensively studied as concluded by Harper (1960). To quote his words, "Weeds have for many years been regarded as slightly improper material for biological studies, and almost all aspects of their biology except those directly related to control measures have been badly neglected". Among biological aspects of weeds, the autecological study is of considerable importance and should therefore, be given due attention. The present paper embodies certain autecological observations made on *Euphorbia dracunculoides* Lamk. which is one of the dominant weeds of 'Rabi'[3] crops.

Geographical distribution :

It is distributed from Punjab to Bihar in the plains and low hills, southwards to Canara and Coromandel, and also westwards to Arabia and Tropical Africa (Hooker, 1885). Duthie (1915) reports its occurrence in cultivated fields of North West India, Moradabad, Sub-Himalayan tracts in Rohilkhand and North Oudh, Bundelkhand and Bengal. Its distribution as given by Bamber (1916) is from plains to 3,000 ft. in Punjab and Baluchistan. It is also found in Bombay Presidency (Cooke, 1906–1908) and in Bettiah and Chhota Nagpur (Haines, 1921) and all over the state of Bihar as a crop weed (Thakur, 1954).

Habit and Habitat

E. dracunculoides, an erect annual herb, has been observed to infest wheat, barley, gram, pea and mustard crops at Varanasi. It is rarely found outside the crop fields.

Root system

The primary profusely branched tap root penetrating up to a depth of 15–40 cm and with a lateral spread of 10–23 cm makes the weed capable of competing successfully with the associated plants.

Leaf

Lower leaves are comparatively longer than the upper ones which are shorter and broader at the base. Midrib usually, though not always divides the leaves into two unequal parts (figure 1).

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Fruit and Seed

Fruit is stalked (stalk length varies from 3-4·5 mm), smooth, pale coloured when dry, and is provided with three distinct and almost equal lobes. Length varies from 3·5–4·5 mm and breadth from 3–3·5 mm. It breaks into 3 one seeded cocci (figure 1). The pericarp of the fruit is intimately fused with the seeds.

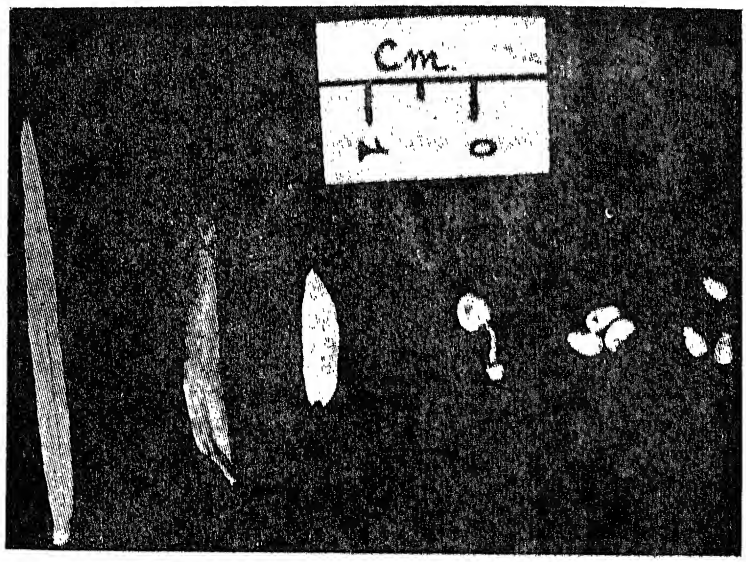

Fig. 1. A lower leaf (extreme left), upper leaves, capsule, cocci and seed of *Euphorbia dracunculoides* Lamk.

Seeds which are usually 3 in each fruit, are ellipsoid, slightly rounded at the base, and grooved on one side. Coruncle lying at the oblique depressed apex is suppressed. Seed coat is hard and leprous (provided with brownish and whitish spots).

Size of the seed varies from 1·8 – 3 mm × 1·4 – 2 mm, the average values for length and breadth being 2·4 and 1·7 mm respectively. The shape index as indicated by length/breadth ratio, varies from 1·3 to 1·5. The average weight of 100 seeds is 38 mg.

Dispersal

The fruit of *E. dracunculoides*, as indicated earlier, breaks open into three one-seeded cocci which are dispersed from field to field mainly through sowing of contaminated crop seeds, and by application of farmyard manure which also contains weed seeds.

Phenology

Seedlings appear in cultivated fields usually in the first week of November and make vegetative growth upto the first week of December. By mid December, about 50 per cent plants of the local population are seen in flowers. The peak period of flowering is first week of January. Fruiting which closely follows flowering, continues upto the end of May. The weed has been observed to be present in the fields after the crop harvest also, and sometimes the plants continue their existence even upto the last week of June.

Seed germination

Seeds collected in April, 1962, 1963 and 1964 were separately dry-stored in corked glass bottles. These seeds were put to germination tests under various conditions. For germination tests, the seeds were placed between moist filter papers in Petri dishes.

Storage in relation to germination

Seeds could not be germinated upto a period of 5½ months after collection. Seeds collected in April, 1962, 1963 and 1964 were separately tested for germination in December, 1964 at room temperature (20–23°C). The results are presented in table 1.

TABLE 1

Effect of storage and scarification on seed germination of Euphorbia dracunculcoides *Lamk.*

Storage period in months	*% gemination in one month test period (non scarified seeds)	*% germination in one month test period (scarified seeds)
8	0	42
20	0	54
32	6	46

Though increase in storage period appears to bring about some germination, the main factor preventing germination is the hard testa. Thus, after mechanical scarification, percentage germination in all the collections irrespective of storage period, increases (table 1).

Germination as affected by scarification and temperature

Seeds collected in April, 1964 were scarified mechanically and with the aid of concentrated sulphuric acid, and were tested for germination in December, 1964 at room temperature (20-23°C). Germination was also tried at two other temperatures indicated in table 2.

TABLE 2

Effect of scarification and temperature on seed germination of Euphorbia dracunculoides *Lamk.*

Treatments	% germination in one month test period
Mechanical scarification	
(*a*) Rubbing with sand paper for 2 min.	0
(*b*) Removal of seed coat	42
Acid scarification	
(*a*) for 2 minutes	4
(*b*) for 5 minutes	8
(*c*) for 10 minutes	2
(*d*) for 15 minutes	0
Control (no scarification)	0
Temperature conditions	
(*a*) 33 ±2°C	0
(*b*) 13 ± 2°C (for 17 hours) daily alternating with 20 – 24°C (for 7 hours)	10

*Values based on 100 seeds in each case.

It is apparent (table 2) that the highest percentage germination (42%) is obtained on removal of seed coat. Acid scarified seeds do not show appreciable germination, the highest percentage (8%) being observed in case of seeds soaked with concentrated sulphuric acid fot 5 minutes. 15 minutes treatment, however, has got damaging effect. Fluctuating temperature is helpful for seeds to germinate.

Seed viability and germinability as related to degree of maturity of fruit

Seeds were collected separately from 3 categories of fruits, *viz.*, less developed and green, fully developed but green, and ripened and dried, in April, 1963. These seeds were separately tested for viability and germination in December. 1964. Data set in table 3 reveal that though percentage germination is nil in all the cases, a good percentage of seeds from green fruits remains viable.

Reproductive capacity

Reproductive capacity of a species is a valuable attribute and is an important factor in successful colonization. It is defined as the product of the average seed output and the fraction represented by the average percentage germination (Salisbury, 1942). By taking into account the maximum values obtained for these, the reproductive capacity of this weed works out to be 254.

Germination stages and seedling morphology

Germination is epigeal. In presence of sufficient moisture, seeds absorb water and swell up, after which testa breaks open and radicle grows out of the seed through the end which bears depressed coruncle. Plumule also starts elongating upwards carrying the cotyledons still enveloped by ruptured testa, and after about a week, a pair of cotyledonary leaves with an approximate length of 1·5 cm is seen, while radicle develops into root system. After about 12 days second pair of leaves appears.

Growth performance

Plants of *E. dracunculoides* were collected in early April, 1964 from the selected wheat fields of Agricultural Farm of Banaras Hindu University and their performance was noted. The summary of observations is given in tables 4, 5 and 6.

As revealed by the data (tables 4, 5 and 6), the best growth is attained in field W_4, while the plants growing in field W_2 show the poorest growth.

TABLE 3

Viability and germination of weed seeds collected from the fruits of different degrees of maturity

Degree of maturity of seeds	Viability* (%)	% germination* in one month
Seeds from less developed and green-fruits	46	0
Seeds from fully developed but green-fruits	76	0
Seeds from ripened and dried fruits	98	0

*Values based on 100 seeds in each case.

TABLE 4

Plant height, spread, number of branches per plant, length and breadth of leaf and penetration and spread of root of E. dracunculoides *in different wheat fields*

(Values represent the average 10 of plants in each case)

Characters	Wheat fields				
	W_1	W_2	W_3	W_4	W_5
Plant height (cm)	21·8	29·3	30·8	32·8	38·8
Spread (cm)	15·2	11·4	15·0	16·7	15·5
No. of branches/plant	6·0	3·0	8·0	7·0	5·0
Leaflength (longest leaf)	3·0	3·3	3·3	3·2	3·9
Leafbreadth (cm)	0·4	0·4	0·35	0·4	0·4
Root penetration (cm)	26·9	26·5	31·9	34·5	32
Root spread (cm)	14·7	10·6	15·5	14·8	14·3

TABLE 5

Fresh and dry weight of shoot and root, and shoot/root ratio of E. dracunculoides *in wheat fields*

Characters	Wheat fields				
	W_1	W_2	W_3	W_4	W_5
*Fresh wt. shoot (g)	11·8	4·3	16·4	19·9	9·7
*Fresh wt. root (g)	1·1	0·66	1·77	2·05	0·94
S/R ratio (fresh wt. basis)	10·9	6·5	9·3	9·7	10·4
*Dry wt. shoot (g)	4·05	1·64	5·6	7·0	2·74
*Dry wt. root (g)	0·345	0·258	0·702	0·724	0·328
S/R ratio (dry wt. basis)	11·7	6·3	7·9	9·7	8·4

*Values obtained by dividing the combined weight of shoot or root of 10 plants by 10.

TABLE 6

Number of fruits per plant, number of seeds per fruit and seed output per plant of E. dracunculoides *in wheat fields*

Characters	Weat fields				
	W_1	W_2	W_3	W_4	W_5
*No. of fruits/plant	170·10 ± 132	60·32 ± 33	153·54 ± 93	164·78 ± 104	70·94 ± 56
**No. of seeds/fruit	2·75	2·80	2·90	2·85	2·79
Seed output/plant	468	169	445	470	198

*Values represent the average of 50 plants.
**Values represent the average of 100 fruits.

Edaphic relations

Certain physical and chemical characters of the surface soil (15 cm) of the fields under study are given in table 7.

TABLE 7

Physical and chemical properties of the soil (top 15 cm layer) collected from wheat fields under observation

Characters	Wheat fields				
	W_1	W_2	W_3	W_4	W_5
+pH	7·2	7·0	7·1	7·2	7·3
+Water soluble salts (×·597 mhos)	$8·5 \times 10^{-5}$	$7·3 \times 10^{-5}$	$7·8 \times 10^{-5}$	$7·8 \times 10^{-5}$	$7·9 \times 10^{-5}$
*%Moisture (late Dec.)	9·87	6·93	6·35	9·62	5·94
*%Moisture (late Mar.)	1·94	2·07	1·87	1·95	1·88
+%Water holding capacity	37·9	38·7	39·2	39·2	40·5
+%Total nitrogen	0·054	0·041	0·063	0·062	0·048
+%Organic matter	1·30	0·735	1·785	1·445	1·33

*Values represent the average of 3 samples.
+Values obtained from composite samples of 4 samples.

A comparative study of tables showing performance of the plants (tables 4, 5 and 6) and the soil characters (table 7) indicates that there exists no correlation of growth with soil characters other than nitrogen and organic matter contents of the soil. These two are directly correlated with the growth performance. The fields rich in nitrogen and organic matter provide more favourable substrata for growth of the plants.

Biotic relations

E. dracunculoides is commonly attacked by the rust, *Melampsorahe lioscopieae* (Butler ond Bisby, 1934). Sometimes the weed growth is severely affected by this fungus.

Crop growth is another factor affecting the weed growth. In fields W_3 and W_4 where crop is sparse (table 8) the weed shows better growth while in fields with higher crop density, the weed growth is poor. Besides crops, other weed species also grow as associates of *E. dracunculoides* but the total weed density could not be correlated with the growth performance.

TABLE 8

Crop density and total weed density per sq. metre in the wheat fields under observation

	Wheat fields				
	W_1	W_2	W_3	W_4	W_5
Crop density	32	29	11	11	23
Total weed density	85	149	147	187	58

Agricultural operations also did not vary distinctly in the fields, and hence no explanation for the differences observed in performance of the weed in different fields could be based on agricultural practices.

Experimental

Experiment 1—Response to clipping.

During the process of hand-pulling of weeds which is commonly employed in the area for weed elimination, majority of the weed plants escape complete removal and a small portion of the shoot remaining intact with the underground parts grows and again develops into a full plant. The clipping experiment described below was conducted to simulate the effects of hand pulling of weeds.

Seedlings of uniform size of *E. dracunculoides* were transplanted in earthenware pots of equal size in second week of December, 1962. After the seedlings were established in the pots, their number per pot was reduced to nine. Afterwards, the plants were given the following treatments :

(1) Clipped at vegetative stage (early January, 1963),

(2) Clipped at flowering stage (early February, 1963).

(3) Clipped at vegetative and flowering stages both (early January and early February, 1963).

Apart from these three treatments, one set was maintained as control (unclipped) For each treatment, 3 replicates were kept. Clipping of the plants was done 4 cm above the soil surface. Plants from each pot were washed in the middle of April for recording the observations. Data are presented in tables 9 and 10.

It is apparent (table 9) that the plant height and number of capsules per plant are reduced due to clipping. The plants clipped twice (at vegetative and flowering stages both) were the most adversely affected, while those clipped at vegetative stage show the performance only slightly poorer than that of unclipped plants. The plants clipped twice and at vegetative stage show increase in number of branches over the control plants. The plants clipped at flowering stage only, however, bear less branches than the unclipped plants. Lateral spread of shoot is reduced by clipping and the most pronounced effect is observed in the plants clipped twice.

TABLE 9

Effect of clipping on growth of Euphorbia dracunculoides

Characters*	Unclipped	Clipped at vegetative stage	Clipped at flowering stage	Clipped at both stages
Plant height (cm)	14·4 ± 5	13·1 ±2·4	11·8 ±2·1	10·7 ±1·6
Shoot spread (cm)	7·9 ±1·5	7·1 ±1·1	7·3 ±2·0	5·8 ±7·1
No. of branches/plant	4 ±1	5 ±2	3 ±1	5 ±1
No. of capsules/plant	39 ±15	32 ±15	30 ±14	21 ±1
Root penetration (cm)	23·8 ±4·3	19·4 ±2·6	24·3 ±4·7	22·7 ±1·3

*Values for each item represent the average of 27 plants.

From the data set in table 10, it is apparent that fresh and dry weight of shoot and root of *E. dracunculoides* are decreased on clipping. Reduction is most pronounced in the plants clipped at both vegetative and flowering stages. The plants clipped only at vegetative stage show less reduction as compared with the plants under other treatments.

TABLE 10

Effect of clipping on fresh and dry weight of shoot and root, and shoot/root ratio of Euphorbia dracunculoides

Characters	Unclipped	Clipped at vegetative stage	Clipped at flowering stage	Clipped at both stages
*Fresh wt. shoot (g)	1·807	1·543	1·192	0·981
*Fresh wt. root (g)	0·775	0·535	0·314	0·210
S/R ratio (fresh wt. basis)	2·33	2·87	3·79	4·67
*Dry wt. shoot (g)	0·496	0·453	0·452	0·311
*Dry wt. root (g)	0·125	0·11	0·09	0·065
S/R ratio (dry wt. basis)	3·97	4·12	5·02	4·78

*Values in each case represent the average of 27 plants.

Ezperiment 2—Response to different irrigation intervals.

Weeds alongwith the crop get the benefit of irrigation, the frequency of which varies from field to field. In order to investigate whether the variation in irrigation interval influences the performance of the weed, the present experiment was conducted during the period of December, 1962 to April, 1963.

Uniform seedlings were transplanted in earthenware pots filled with arable soil on 21st December, 1962. After the seedlings were established, their number per pot was reduced to nine, and the plants were subjected to following irrigation treatments :

(1) irrigated daily,

(2) irrigated twice a week, and

(3) irrigated once a week.

Three pots were set for each treatment and the observations were recorded in middle of April which coincides with harvesting period of the crops. Data obtained are presented in tables 11 and 12.

Performance of the weed as indicated by plant height, shoot spread, number of capsules per plant, and rooting depth is directly proportional to decrease in irrigation interval, *i.e.* increased frequency of irrigation favours the growth of this weed (tables 11 and 12).

A direct correlation exists between the fresh and dry weight of shoot and frequency of irrigation. The plants watered once a week, however, show higher values for fresh and dry weight of root than the plants subjected to twice-a-week irrigation.

TABLE 11

Plant height, spread, number of branches and capsules per plant and root penetration in relation to irrigation intervals.

(Values in each case represent the average of 27 plants)

Characters	Irrigated daily	Irrigated twice a week	Irrigated once a week
Plant height (cm)	13·2 ±1·9	11·4 ±2·2	10·4 ±1·3
Shoot spread (cm)	5·5 ±0·5	5·7 ±1·6	4·2 ±1·1
No. of branches	4 ±1·4	4 ±1·4	4 ±1·4
No. of capsules/plant	35 ±12	23 ±9	20 ±6
Root penetration (cm)	25·1 ±8·5	19·2 ±1·8	16·4 ±6·4

TABLE 12

Effect of irrigation intervals on fresh and dry weight of shoot and root, and shoot/ root ratio of Euphorbia dracunculoides

Characters	Irrigated daily	Irrigated twice a week	Irrigated once a week
*Fresh wt. shoot (g)	1·027	0·928	0·607
*Fresh wt. root (g)	0·269	0·179	0·227
S/R ratio (fresh wt. basis)	3·8	5·2	2·7
*Dry wt. shoot (g)	0·382	0·286	0·266
*Dry wt. root (g)	0·084	0·070	0·073
S/R ratio (dry wt. basis)	4·5	4·1	3·6

*Values in each case represent the average of 27 plants.

Discussion

Phenological observations on the weed indicate that it continues to be present in the fields even after the crop harvest. Through phytosociological studies also, it has been shown that the values for density, frequency and cover of the weed remain less affected by the temperature relations of the environment (Tripathi, 1965). Deep penetrating and well spread root system may be a factor contributing to the success of the weed. Because of its presence in the field for longer duration, the seed production per plant of the weed may be much higher than what has been recorded. Besides many other precautions, care should, therefore, be taken to remove the weed plants from the fields as soon as crop harvest is over in order to minimize the infestation of this weed.

Germination studies indicate that there may be some after-ripening period of the embryo, but the main factor which prevents the seed germination is the hard

seed coat as revealed by the comparison of the germinability of the scarified and unscarified seeds. The fact indicates that scarification, irrespective of storage period may do so entirely because of some changes in the testa itself rather than the after-ripening period of embryo. This point, however, needs further experimentation in order to reach a definite conclusion. Viability tests indicate that the seeds collected from green capsules also remain viable (table 3) which helps the weed in escaping the human efforts made for its elimination. Immature weed seeds have also been reported to be viable by Gill (1938), Brenchley and Thurston (1948) and Chakravarti and Pershad (1953).

Out of the physical and chemical characters of the soil studied, only nitrogen and organic matter contents have got direct correlation with the growth performance of the weed. Other characters, however, do not vary much from field to field and as such no correlation of these with growth could be expected. The detailed study of the edaphic relations of the weed may, however, reveal certain interesting facts.

The fact that weed growth suffers seriously due to attack of *Melampsora helioscopieae*, suggests the biological means as one of the control measures of this weed. Further, the high crop density has been observed to suppress the weed growth (table 8) persumably by offering competition to weeds for different growth requirements (Tripathi, 1967). This is another point which may be taken into account while planning the weed elimination.

The results of clipping experiment which was conducted to simulate hand pulling of weeds so commonly employed in the area for weed removal, indicate that the weed under study is quite tolerant to removal of aboveground portions. However, the frequent removal of aboveground parts may bring about considerable reduction in growth. Frequent irrigation is helpful to crops but at the same time the weed plants also derive benefit as revealed by the results of the experiment done to study the response of *E. dracunculoides* to irrigation interval. However, the decrease in frequency of irrigation as means for its control is not advisable as this may affect the crop materially.

Summary

The paper incorporates certain autecological notes on *Euphorbia dracunculoides* Lamk. which is one of the dominant weed species infesting the 'Rabi' crops. Its geographical distribution, habit and habitat, certain morphological characters, dispersal and phenology have been described, seed germination has been tested and the growth performance of the weed collected from the selected wheat fields has been recorded.

Storage and scarification (acid and mechanical) increase the germinability of the seeds. Fluctuating temperature also favours the germination. Hard seed coat has been reported to be the main factor preventing seed germination. Seeds from green capsules also remain viable.

The growth performance of the weed is poor where the crop density is high. The soils rich in organic matter and nitrogen favour the weed growth as also the frequent irrigation. Casual removal of aboveground parts only, does not ensure the control of the weed.

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Ecology of *Cyperus rotundus* L. III. Population of tubers at different depths of the soil and their sprouting response to air drying

By

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Introduction

Underground tubers and basal bulbs are the most effective means of propagation of *Cyperus rotundus* L. These parts are found buried in the soil to different depths. Tubers situated in surface layers are likely to be desiccated during dry weather. Desiccation of tubers may adversely affect their sprouting. Estimation of the population of the perennating structures at different depths and their response to air-drying is therefore, discussed in the present paper.

Experimental Procedure and Results

Tuber population in soil: The population studies of tubers were made in July, 1965 in a local (inside the University campus) wheat field moderately infested with *C. rotundus*. The density of this weed was 26–35 aerial shoots per 30 × 30 sq. cm. the average being 31. Five sites of 30 × 30 sq. cm. area were selected for population estimation. On all the sites, the tuber population at different depths of the soil (0–10, 10–20, 20–30, 30–40 cm) was determined separately by digging out the respective layers one by one and by counting the tubers present therein. The data thus obtained are set in table 1.

TABLE 1

Tuber population of C. rotundus L. *at different depths of the soil*

Soil depth (cm)	Sites				
	1	2	3	4	5
0–10	97	128	167	111	147
10–20	79	76	106	66	55
20–30	16	9	15	10	7
30–40	0	0	0	0	0
Total tuber population per 30×30 sq. cm.	192	213	288	187	209

A perusal of the above table reveals that the population of the tuber in soil is very high varying from 187–288 per 30 × 30 sq. cm. of the wheat field. Further, the tubers are confined only upto 20 cm depth. The maximum number of tubers is found in the top layer, *i.e.*, 0–10 cm depth. With increase in depth the tuber population goes down.

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The data on tuber population were subjected to statistical analysis for the test of significance (*see* table 2).

TABLE 2

Analysis of variance of the data in table 1

Source of variation	Degree of freedom	Sum of squares	Mean sum of sq.	Observed 'F' (Variance ratio)	'F' at 5%	Values at 1%
Spots	4	1716	429	0·744	3·26	5·41
Depth	3	51039	17013	29·588	3·49	5·95
Error	12	6906	575			
Total	19	59661				

The observed value of 'F' for spots is less than the table value of 'F' at 5% and 1% levels of significance (table 2) showing the insignificant difference in the values of tuber population obtained at different spots, *i.e.*, the tubers in the entire wheat field are uniformly distributed. On the other hand, the observed value of 'F' for depth is far greater than the table value of 'F' at 5% and 1% levels of significance. It is, therefore, concluded that tuber population of *C. rotundus* at different depths, of the soil differ significantly.

Response of tubers to air drying : Tubers of *C. rotundus* used in this experiment were collected on 27th November, 1965 from the garden of the department of Botany, Banaras Hindu University. After careful washing, 3 lots of 20 tubers each were separated for determining moisture content after different days of air drying in laboratory at 22–26°C. The rest of the tubers (to be used for sprouting) were also kept in laboratory for air-drying. With the days of air-drying, tubers started losing weight. However, after 16 days of air-drying they did not show further loss in weight. Ultimately the 3 lots of tubers were kept in an oven maintained at 80°C to find out the dry weight of tubers. The moisture content of air-drying tubers was calculated on the basis of dry weight. Simultaneously the air-drying tubers from the big lot were kept for sprouting at 30°C. The data regarding the effect of air-drying on moisture content of tubers and the sprouting of tubers air-dried for varying days are given in table 3.

TABLE 3

Percentage moisture content of air-drying tubers of Cyperus rotundus *L. in relation to their sprouting*

Days of air drying	*Percentage moisture content	*Percentage sprouting
0	182·7	65
2	105·5	63·3
4	66·6	38·3
8	28·8	13·3
12	16·1	10
14	13·0	0

*Values represent the average of three replicates with 20 tubers each.

It is quite evident from table 3 that the tubers of *C. rotundus* lose water rapidly when kept for air-drying after 14 days of air-drying, moisture content of tubers is reduced to 13% from 182·7%.

Sprouting percentage decreases with decrease in moisture content of tubers. Tubers air-dried for 12 days containing 16·1% moisture show only 10% sprouting. Tubers fail to sprout when the moisture content of the tubers is further reduced as is the case with tubers air-dried for 14 days (table 3).

Discussion

The magnitude of infestation of this weed in fields is generally recognised by the density of aerial shoots, which is far less than the tuber population in soil. So the real infestation by this weed is many times that represented by the aerial shoots because in due course of time the tubers lying dormant may also sprout. It is, therefore, suggested to remove the tubers of this weed from the fields as carefully and thoroughly as possible. The difference in density of aerial shoots and underground tuber population, however, may be attributed to insufficient aeration of the deeply buried tubers and/or to system-apical-dominance exhibited by the chains of tubers of *C. rotundus* (Smith and Fick, 1937 ; Muzik and Cruzado, 1953).

The facts that majority of tubers lies in surface 10 cm. depth of the soil and that they are very susceptible to air-drying (Smith and Fick, 1937) may be exploited for destruction of the tubers by somehow disconnecting the tubers of upper stratum from deeply placed system of rhizomes and tubers which keep them alive by supplying the requisite quantity of nutrients and water.

The percentage moisture content of tubers is quickly lost on air-drying (table 2) andspercentage sprouting goes on decreasing with loss in moisture content of the tuber. The tubers with 16·1% moisture show only 10% sprouting which ceases when moisture percentage reaches 13%. This indicates that there is some critical moisture content of tuber (most probably between 13·0 and 16·1%) below which the tubers lose their capacity to sprout.

Conclusions

The tuber population of *C. rotundus* in soil is very high (187-288 per 30 × 30 sq. cm.) and majority of them is distributed in top 10 cm layer. With increase in soil depth, tuber population decreases and no tuber is found beyond 30 cm depth.

There is quick loss in moisture content of tubers when they are allowed to be air dried. With loss in moisture content, the sprouting percentage decreases. Data collected on moisture loss and sprouting behaviour of air dried tubers suggest that critical moisture content of tubers may be between 13 and 16·1%. When there is further loss in moisture content of tubers, they fail to sprout.

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Contribution to the ecology of Indian aquatics II. Studies on the growth rate of 'Duck-weeds' [*Lemna minor* Linn. and *Spirodela polyrrhiza* (Linn.) Schleid] under laboratory conditons

By

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Lemna minor Linn. and *Spirodela polyrrhiza* (Linn.) Schleid are small, free-floating aquatics, distributed throughout in stagnant and slow-flowing waters of India. During our investigation on the bio-ecology of a perennial lake (Ramgarh) of Gorakhpur, it has been observed that the growth of these plants was too rapid and certain barren areas of littoral regions were covered within a short time. The flowering in plants was never observed during the period of study although it has been reported to occur by Saeger (1929) and Maheshwari (1958). The only means of their adventive spread was through vegetative propagation. The present work is a contribution to the rate of production of these two plants under laboratory conditions.

For each set of experiments, 5 g pure samples of *L. minor* and *S. polyrrhiza* were taken during November, 1968, from culture pots of the University botanic garden. They were washed thoroughly in running tap water and then transferred to two sets of small glass troughs, one containing the tap water and the other having Hoagland's solution. Each set (comprisiing of 14 troughs) was kept in diffused day light. The room temperature during the period of study (4 weeks) was 25±5°C. The readings in the biomass increase were taken at 4 days intervals in each set and the rate of production/g/day were calculated. The results are expressed in terms of organic weights, determined according to Westlake (1963, 1965).

TABLE 1

Growth rate of L. minor *and* S. polyrrhiza *in tap water and Hoagland's solution*

Days	Weight of Organic matter (g)			
	In Tap Water		In Hoagland's Solution	
	L. minor	S. polyrrhiza	L. minor	S. polyrrhiza
0	0·44	0·42	0·45	0·45
4	0·62	0·50	0·62	0·66
8	0·85	0·58	1·23	1·40
12	1·25	1·50	2·00	2·61
16	2·20	3·00	3·25	3·60
20	2·50	3·20	3·76	4·21
24	2·48	3·05	3·85	4·00
28	2·40	2·90	3·82	3·96

The data obtained on the rate of growth and biomass change are given in Table 1 and 2 respectively.

TABLE 2

Rate of Biomass change of L. minor *and* S. polyrrhiza (*g/g/day organic matter*)

Days	Rate of Change (g)			
	In Tap Water		In Hoagland's Solution	
	L. minor	S. polyrrhiza	L. minor	S. polyrrhiza
0– 4	+0·102	+0·048	+0·094	+0·118
4– 8	+0·109	+0·04	+0·25	+0·30
8–12	+0·119	+0·41	+0·15	+0·218
12–16	+0·19	+0·25	+0·15	+0·098
16–20	+0·034	+0·16	+0·04	+0·043
20-24	−0·00002	−0·001	+0·0006	−0·0012
24–28	−0·0006	−0·0012	−0·0004	−0·000025

It is evident from Table 1, that organic matter invariably increased in all the cases upto 20th day of experiment (except in *L. minor*, growing in Hoagland's solution, where the increase continued till 22nd day) and started declining gradually thereafter.

The total net production (*i.e.* the net increase of organic matter from the initial biomass samples to the samples of maximum biomass) was 2·06 g. and 3·39g organic matter in *L. minor* and 2·78g and 3·75g in *Spirodela polyrrhiza* growing in tap water and Hoagland's solution respectively. Further, maximum biomass values were always obtained in *S. polyrrhiza* in comparision to *L. minor*.

The maximum rate of biomass change was found as 0·41 g/g/day and 0·30 g/g/day in tap water and Hoagland's solution in *S. polyrrhiza* and 0·19 g/g/day and 0·25 g/g/day in case of *L. minor* respectively (Table 2).

The data show that although considerable amount of organic matter is produced by these tiny plants at a rapid rate but this remains unexploited for the human welfare and is returned back to soil after decay. Biswas and Calder (1935) have pointed out the beneficial action of these plants in purifying foul water, particularly, those surcharged with organic impurities and making such waters conducive for other water plants.

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Ecological studies on the weeds of agricultural fields (1). Persistence of *Portulaca quadrifida* L. against desiccation

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Adaptability of weeds to eradication—practices is a great problem in agriculture. Their recurrence subsequent to removal of aerial parts depends upon their propagules present in soil, the incidence and magnitude of their infestation (Harper, 1959), their capacity to produce viable propagules after cutting and their ability to root again. The chances of their survival increase manifold when such weeds multiply vegetatively also, along with prolific seed production (Bunting, 1959) and are drought tolerant (Bunting and Lea, 1957).

Portulaca quadrifida, a notorious weed of regularly irrigated fields, has been seen to occur on river-sand-bed in crevices between boulders of hills and on saline sand near sea-coast. In coastal areas they are infrequently found in rocky-strand habitat, specially in small rocky-crevices. On the basis of analysis, the nature of the rock is reported to be dolomite limestone with impurities of SiO_2 and R_2O_3 and at no time they form a thick vegetal cover on the rock-surface (personal communication with the Director, B. S. I., Calcutta). They are also found growing well on gravelly-sandy soil. This is a plant of fore-shore sandy vegetation at Kanya-Kumari (personal visit). The region is characterised by the scant and open vegetation which is due to physiological dryness of the soil, scanty rainfall and strong wind-velocity. Sabnis (1919) studied this plant also along with others of arid-zones.

However, the plant has been seen by the author, forming thick reddish-green patches in vegetable fields, at a number of places in the country, (Fig. 1). Somehow or other, these patches are usually recurred in the next crop, even after their perfect removal by farmers from these fields. This led to a detailed ecological study of this weed. Observations and experiments on its adaptive response to desiccation is the first information from the detailed study of the plant species.

Methods and Materials

Field observations: A large number of places have been visited and the plant specimens of National Herbarium (Calcutta), Herbarium-sheets of F. R I. (Dehradun), B. S. I. western circle (Poona) were examined to find out the distribution of the plant in India.

To determine moisture-content of soil, samples were brought to the laboratory in tight glass bottles. After fresh-water determination these were kept at

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105°C in oven till constant weight. The moisture-content is expressed as percentage of its dry-weight.

Experimental work : Plants of different age-classes were raised originally from the seeds. After emergence of seedlings all but one of them, were removed. Intervals between sowings of seeds were so adjusted as to make available the plants of following age-classes at the same time :

(I) Cotyledonary-leaf stage . . 2 leaf stage.
(II) Early-leafy stage . . The plant became prostrate.
(III) Late-leafy stage . . The plant started developing lateral branches.
(IV) Early-flowering stage . . Started flowering.
(V) Late-flowering stage . . Started flowering and fruiting.

The plants were singly sown in 20 cm pots. Up-rooting was done with the help of a scalpel and uprooted plants were kept on the soil of the same pot after careful removal of their roots. The plants under drought treatment ceased to get any supply of water and were exposed to weather conditions of the season. Drought-tolerance is expressed here as the length of time of survival of the plant under drought conditions, as was originally devised by Tumanov (1927) and modified by Waisel (1959) and Levitt (1956) (referred by Levitt, 1965). Since the aim of studying such characteristics has been to determine the drought-resistance as a cause of persistence of the weed, the experiments were performed under natural conditions in two seasons *viz.*, summer and winter. Drought-avoidance is expressed here by comparing rate of transpiration. Quick weighings were performed on an ordinary Torsion-Balance with an accuracy of $\pm$ 0, 2% of measuring range.

Anatomical studies : Free-hand sections were used to study the anatomy of the plant. Sections were first seen under water-preparations and without giving any stain. Later on, sections were stained with safranin and glycerine-preparations were made.

Field-observations

The common cultivation-operations for the removal of the weed in vegetable-fields are cutting of the weeds followed by subsequent drought (*i.e.*, irrigation stopped) or at times either uprooting followed by subsequent watering or drying without uprooting, at different times during the growth of the weed and crop-plants. Uprooted plants are generally collected in heaps (Fig. 2), or they are left in the field for drying (Fig. 3). Such uprooted plants of some weed-species were collected and were allowed for their re-establishment in pots. On watering to these pots, fragments of *P. quadrifida* were able to resume growth. Except this weed and *P. oleracea*, uprooted plants of rest of the weeds, such as *Sonchus oleraceus*, *Elecusine indica*, *Trianthema portulacastrum*, *Amaranthus spinosus*, *A. sp.*, *Chenopodium album* were not able to establish.

Soils of these fields are disturbed several times in a year, thus creating adverse conditions for the survival of the weed. Atleast 3-4 occasions in a year can be characterised as drought-periods, when old crops are harvested and weeds are left for desiccation, before new crops are sown. These drought-periods come in the months of September-October, January-February and April-June. Moisture-percents of the soil samples collected on the same day and time at a depth of 10 cm from the surface have been determined from four places in a vegetable field and

a comparison has been made with those of neighbouring field which were not under cultivation, and natural habitat of the plant (Table I).

TABLE I

Percent Moisture of the soils of the fields

(Values are averages of four replicas)

Locality	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Vegetable Field	14·5 ±1·2	23·8 ±1·3	22·5 ±2·0	16·5 ±1·9	12 5 ±1·1	10·1 ±1·1	18·8 ±2·5	39·8 ±1·2	38·5 ±1·5	12·0 ±1·5	48·5 ±·12	27·5 ±2·0
Neighbouring Field	12·0 ±1·2	11·8 ±1·3	11·2 ±2·0	10·3 ±1·9	8·6 ±1·1	8·4 ±1·1	17·5 ±2·1	38·5 ±2·3	20·1 ±1·4	14·6 ±1·5	12·5 ±1·6	12·0 ±1·7
Natural Habitat	12·6 ±1·0	10·2 ±1·2	8·7 ±1·0	6·8 ±1·2	6·8 ±1·2	6·5 ±1·0	8·9 ±2·2	14·9 ±1·2	20·1 ±1·5	16·1 ±1·4	16·2 ±1·4	14·2 ±1·7

The natural habitat of *P. quadrifida* in Ujjain is rocky upland (Fig. 4) where it generally persists even up to the end of March. In vegetable fields, where water conditions are relatively better this weed parsists throughout the year. Neighbouring fields were abandoned lands where cultivation operations were rarely tried. While plants developing from the seeds can be seen in crops of June, April and also of October, shoot fragments are the only means of recurrence in January-crop (Table II).

Frequent Farming-operations in form of uprooting used to cause sharp reduction in weed-population. The reappearance of the weed then would be from two sources *viz.*, from seeds or from fragments. It was possibte to differentiate a seedling from a shoot-fragment. The latter developed fibrous-roots at the buried nodal region while the former sent an erect tap-root. Fragments comprising 4-12 nodal size were generally seen although exceptionally fragments with 3 nodal size were also seen. Number of seedlings and fragments were counted in a square-metre quadrat. Each value represents average of ten quadrats.

TABLE II

Regeneration of the weed in different seasons

Locality	Recurrence Period							
	June		October		January		April	
	Seedl.	Frag.	Seedl.	Frag.	Seedl.	Frag.	Seedl.	Frag.
Natural Habitat	8·6	0	–	–	–	–	–	–
Vegetable Field I	14·5	0	6·2	8·9	0	4·8	10·5	3·5
Vegetable Field II	10·2	0	5·5	10·1	0	5·0	15·2	2·8
Vegetable Field III	18·1	0	2·3	8·5	0	5·9	11·5	4·0

Some seedlings and fragments were responsible for the recurrence of the weed in October-crop. However, in January, the total number of propagules was considerably less than that of any other season. Fragments of April-crop did not survive for developing population of June-July, probably due to the lack of the drought resisting capacity. Following experiments were planned to understand the problem.

Drought-tolerance of the weed

Experiments were performed twice, first during the period from March to June, when it was relatively hot and second, during the period between December-February, which was characterized by low-temperature (Table III).

TABLE III

Climatic data of Ujjain (Main study site)

Month	Max. temp. (°C)	Min. temp. (°C)	Rain-fall. (mm)	*Rel. Hum.	Wind Velocity (Km/hr.)	Day Length H.	M.
January	26·6	8·7	18·6	52	3·7	10	52
February	31·2	11·5	10·6	50	3·1	11	19
March	33·7	14·4	9·0	34	4·4	11	59
April	36·9	19·1	0·0	34	8·9	12	39
May	39·8	24·1	7·8	40	14·4	13	14
June	36·9	24·7	80·2	67	10·1	13	32
July	31·0	23·3	296·1	82	17·0	13	25
August	28·6	22·8	315·7	91	13·7	12	56
September	30·4	20·9	123·8	85	10·0	11	20
October	32·1	17·5	25·5	74	2·7	11	37
November	30·9	15·8	34·1	80	–	11	02
December	26·9	10·7	9·6	75	–	10	45

*Average of readings taken at 17 : 30 Hrs. and 08·30 Hrs.

There were two sets of the plants of each age-class, uprooted (U. R. T.) and rooted (R. T.), and each set contained 20 plants. Drought-tolerance is recorded here as period (in days) needed for the death of 50% and 100% of the total plants. Plants were declared dead when the total plant found to be turned black in colour (Table IV). Result of analysis of variance is also given but separately for both the levels of mortality *viz.*, 50% mortality (period in days during which 50% plants died) and 100% mortality (during which all plants taken for experiments died).

TABLE IV

Drought-tolerance of uprooted and rooted plants of different age-classes

*Seasons	**Sub-treatment	Drought-tolerance of the plants *** age-classes indicated									
		I		II		III		IV		V	
		50%	100%	50%	100%	50%	100%	50%	100%	50%	100%
Summer	Uprooted	0·3	1·1	0·4	2·1	2·0	4·0	2·8	8·0	5·0	10·0
	Rooted	6·0	4·0	7·0	26·0	55·0	86·0	70·0	90·0	76·0	90·0
Winter	Uprooted	9·0	10·2	20·1	52·0	27·0	58·0	40·3	60·0	48·0	73·0
	Rooted	14·2	17·2	56·3	67·5	56·5	79·2	69·5	78·0	81·2	25·0

*Variation significant at 5% probability in both levels of mortality period.
**Variation significant at 1% probability also in both levels of mortality period.
***Variation between age-classes significant at 5% probability in both the levels of mortality period.
Variation due to interations between season and sub-treatment not significant.

Drought-tolerance thus appears to increase with age. Rooted plants were considerably more resistant than uprooted ones. Experimental work to explain the cause of such behaviour is in progress and shall be reported elsewhere.

Drought avoidance and its development in the weed

Persistence of the weed against desiccation appears to be due to its succulent nature. Aerial portion of plants which appeared during rainy season in these fields were found to contain as much as 2000-3000 percent water of its dry-weight (equivalent to 90-96 percent of their fresh weight). When subjected to slow desiccation by keeping some uprooted plants of age-class III, in a desiccator, they remained alive for a period more than 6 months. Leaves were the first to dry and to shed. Lateron, an irregular pattern of drying of stem continued leaving only few nodal zones alive. These alive portions were reddish in colour while dead ones were shrivelled and turned black. Three plants were taken for determination of moisture percent after 4 months and were found to contain only 192·5% moisture of the dry-weight of the plant. After five months of desiccation, plants were found to contain only 97·5% moisture. At this stage when some of them were transferred to pot and watered, they were able to re-establish. On further desiccation, moisture was reduced to as low as between 32·3-48·6 percent. These plants were not able to re-establish when allowed to do so.

Of equal significance should be the drought avoiding capacity of the plant. Turgidity conditions were markedly different in plants collected in July and those collected in January. While January-plants found to contain only 300-400 percent moisture, mesic plants contained as much as 1500-2000 percent moisture of their respective dry-weights. Drought avoiding capacity of the plant were determined in these months, in terms of reduction in rate of transpiration. The rate of transpiration of the whole uprooted plant was found to be more in July than in January (Table V). Experiment was continued for the full day in open sunlight and weighings were done after each interval of four hours.

TABLE V

Transpiration-rate of the weed during the Summer and Winter seasons

(Water loss by the plant/hour as precent of its dry weight)

(Average of five replicas in each case)

Month	Age-class				
	I	II	III	IV	V
July	442·60	60·08	40·04	28·40	8·20
January	9·40	5·80	5·00	5·20	5·00

Variations in transpiration-rate due to seasons, between age-classes within seasons, as well as due to interaction between seasons and age-classes are significant at both, 5% and 1% probability levels.

Following experiment was planned to investigate the possibility of development of drought-resistance due to insufficient water supply during the course of their growth.

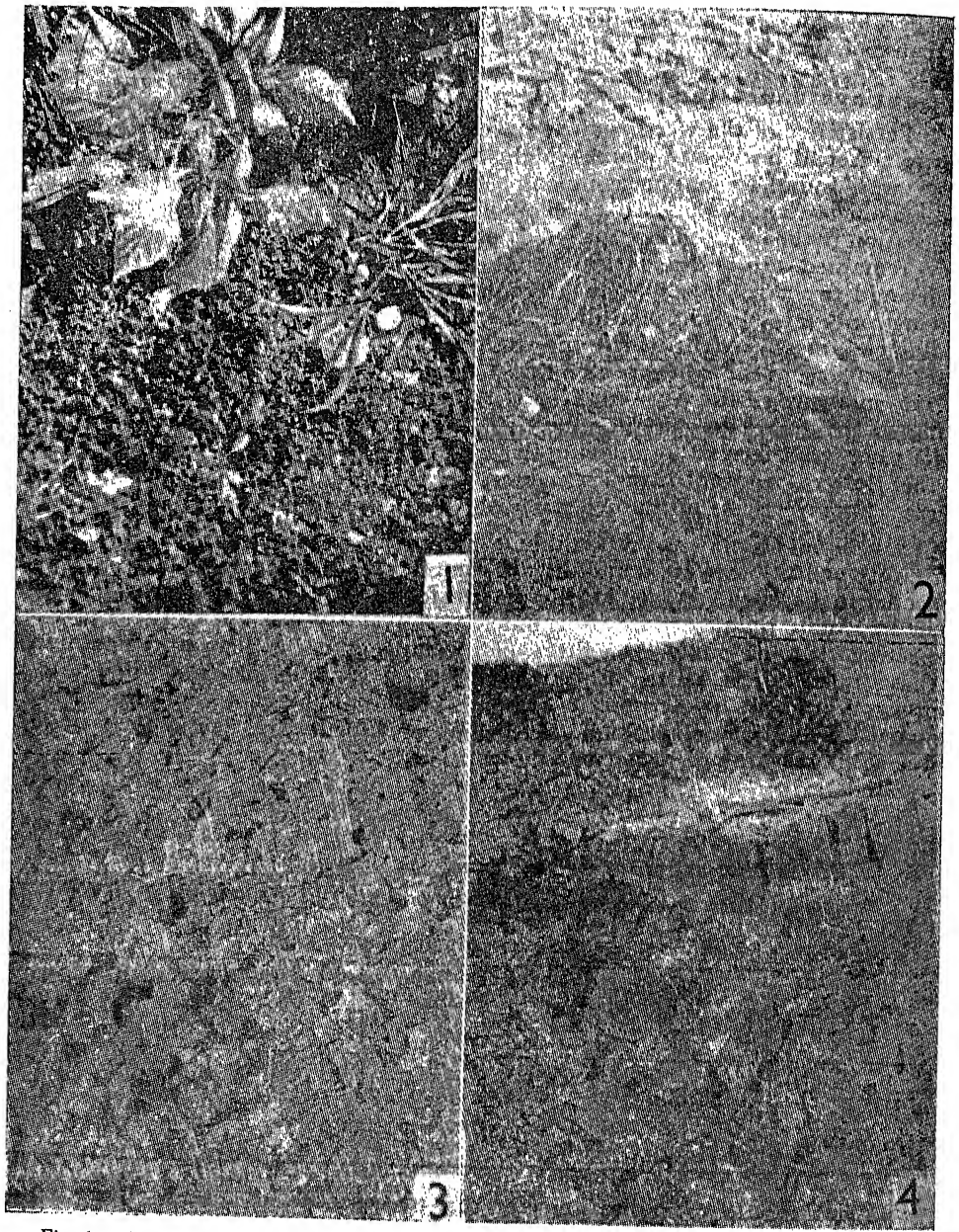

Fig. 1. *Portulaca quatrifida* in chilly field.
Fig. 2. Heaps of *Portulaca quadrifida* gathered outside the field after uprooting along with other weeds.
Fig. 3. Fragments of *P. quadrifida* are seen after ploughing of the field.
Fig. 4. *Portulaca quadrifida* is seen at a rocky upland (natural habitat) along with *Dactyloctenium aegyptium*.

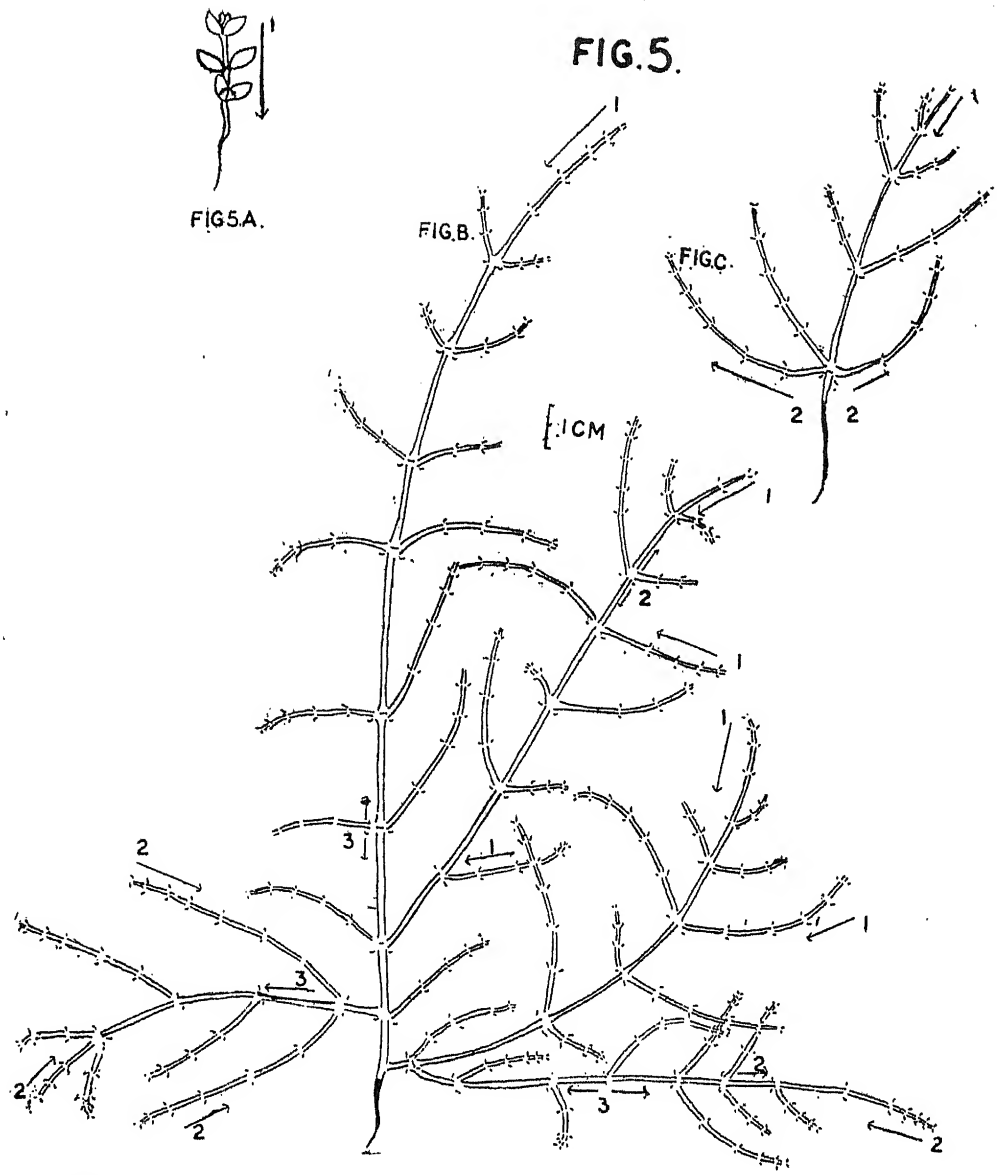

Fig. 5. A, B and C illustrate the progress of desiccation, in directions, as indicated by arrows, of plants of three different age classes. Numbers 1, 2, 3, are sequences of the progress of desiccation with gradual increase in drought-period.

TABLE VII

Analysis of variance for water-holding capacity of xeric and mesic plants.

Variance due to	D. F.	S. S.	M. S. S.	F—from Expt.	F—from Table—at 5%	F—from Table—at 1%
Replications	2	11598	5799	0·91	19·00	99·01
Treatments	1	333177	333177	51·90	18·51	98·49
Residual Error	2	12704	6352	..	—	—
Total	5	357479	—	—	—	—

These changes in the water relations of the plant were further traced in the same generation. Fragments of some xeric plants were buried in the soil and were irrigated daily, thereafter. Fresh green lateral branches emerged, which behaved perfectly similar to mesic plants as regard their rate of transpiration, as well as water imbibition.

In these experiments a peculiar behaviour of this plant has been observed. Young plants grown under watered conditions, whether rooted or uprooted, started drying from apex and this process continued upto the oldest node. This resulted in the death of the plant. All the injured parts turned black. In older plants with greater extension of the prostrate branches this injury was irregular in location. First apical three nodes of lateral branches were always the first to turn black, but later on sequence of desiccation was irregular and did not follow the age-sequence. Some intermediary nodal regions with their leaves dried repidly while rest of the portion remained alive. The oldest internodes of lateral branches usually turned black, thus separating lateral branches from the parent plant. Irregularities, thus followed in drying often omitted some intermediary nodes (Fig. 5). On supplying water to such plants, each fragment with internodes developed in a new plant. This often led to an increase in the number of individuals, as a result of drying operations managed to kill the weed.

Ecological anatomy

Sabnis (1919) had included the species in the list of the desert plants of India and described some salient features of its physiological anatomy.

As the plant seems to belong originally to dry-habitats and now has successfully got accustommed to habitat of relatively better water conditions, the range of plasticity in its anatomical features demand some studies. Plants from following habitats were used for anatomical studies :

(*i*) where water supply was scarce, and

(*ii*) where water supply was abundant. Following interesting feature were noted :

Leaf : Fig. 7 shows that epidermal cells of both the surfaces contain anthocyanin. In epidermal cells of adaxial surface its presence is evident visually also, but adaxial surface of leaves from mesic habitat appeared green. On this surface the colour of anthocyanin is masked by the abundance of chlorophyll. Stomates are restricted only to adaxial (upper, convex) surface. According to

Sabnis (1919) stomata are more numerous on the lower surface. Major portion of the leaf is constituted by aqueous tissue. Vascular bundles of veins present more or less hemispherical structure in transverse section. These are surrounded by palisade parenchyma. Calcium-oxalate crystals are prominent in the leaves of plants from dry habitats. They are more numerous on the adaxial surface.

Veins do not form an intensive net-work in the leaves of this plant and mostly lateral veins end blindly but rarely do connect with veinlets of other veins (Fig. 9). Such examples of open venation are few among angiosperms.

Stem : The stem is herbaceous and devoid of any mechanical tissue or secondary growth (Fig. 6). These are circular in outline. Epidermis is constituted of polygonal cells which are evidently protruberated in mesic stems. Anthocyanin is filled in epidermal cells.

Outer cortical cells are filled with starch granules while inner ones contain chlorophyll. Cortical portion is relatively more in dimension than vascular tissue. The cells surrounding vascular zone contain anthocyanin, which is more prominent among xeric plants. Calcium-oxalate crystals are present in cortical cells.

Generally there are six vascular bundles, two bigger and four smaller, the latter are grouped in pairs and alternate with the bigger ones. The sclerenchymatous paricycle is not developed.

Root : Roots are well protected by developing layers of periderm (Fig. 8).

Discussion

The present study has been undertaken to explain the cause of continuity of the weed from one crop to another in a year and from one year to subsequent ones in a field. From the fact that the plant grows well and only in vegetable fields and in some other well-irrigated localities under cultivation, it can not be assumed that these fields are original habitat of the plant species. Although, now, this species is an important component of the diverse flora of vegetable fields, nevertheless, its original home may be an uncultivated xeric habitat.

The weed regenerates through two types of propagules, *viz.*, seeds and shoot-fragments. While seeds are the major means of regeneration, fragments are also able to pass relatively unfavourable conditions and help the weed to continue through winter, particularly, at a time when seeds are not able to develop into seedlings. On the other hand, summer months form a drastic period for the survival of this weed and atleast uprooted plant can not prolong their life upto the end of drought-period. At any rate, the weed can survive long against desiccation. Drought-tolerance is considerably high in mature plants which are able to survive in winter and greater part of summer when they cease to get water supply. The ability of the weed to propagate vegetatively by fragments guards against weed removal practices. Submortal desiccation, which generally happens in the field, causes detachment of these fragments and is likely to increase the number of individuals, rather than to check the propagation of the weed. For the normal performance of a plant, while transpiring rapidly, there should be a balance between water absorption, the rate of movement of water in the plant and the evaporation from exposed surfaces (Kramer, 1956). In *P. quadrifida*, two opposite leaves with their neighbouring nodal region may dry earlier before they could get any supply of water. Thus the chain of relative distribution of water is broken, resulting in irrecoverable injury to plant parts.

In the present paper some xerophytic as well as xeromorphic features, of the plant, developed during its growth are enumerated. While development of xeromorphic features can be accomplished at any place, cultivation operation can not be held responsible for the development of xerophytic features. Whatever may be the cause of introduction of this weed into the cultivated fields, but present extension of the weed reflects its wider ecological ampltitude. Its absence from other crop-fields, which are not irrigated regularly throughout the year, although their fragments migrate several times to such places, further support the latter interpretation. At present, the question that why the weed is specially localised in these vegetable fields and not found at other places is remained unanswered.

Hemispherical arrangement of palisade cells around the veins provides increased surface for contact and exposure. Upper surface of leaf is characteristically convex, probably helping in dissemination of heat rays. Stomates are localised only on upper (adaxial) surface, as expected in a creeping plant. Observation by Sabnis (1919) in his material from desert localities that stomates are more numerous on the lower surface, is not true for the plants of the habitats described here. Aqueous tissue is located on the lower surface, the lower epidermis is devoid of stomates and possesses anthocyanin. The high turgor of parenchyma may be giving strength to the leaves, specially in the absence of hard tissues.

Thus, in this plant, there appears to be a compromise between water-storing mechanism and one of assimilating tissue in leaf and stem of the plant. This is evident from the following features :

(1) Stomates are localized only on upper surface in the neighbourhood of photosynthetic tissue and not on the lower surface where aqueous tissue is present.

(2) Aqueous tissue occupies the bulk of the leaf and is well represented in stem also.

(3) Hemispherical arrangement of the palisade cells around the vascular bundles.

(4) The peripheral position of the aqueous tissue and the central position of the assimilatory tissue facilitate rapid absorption of the water by the former and ensure protection of the latter from the injurious effects of intense light and heat.

Relatively low magnitude of transpiration-rate and water-holding capacity in xeric plants as compared to mesic ones and their transformation into one or another type on changing the moisture conditions, indicate a high degree of plasticity in the water-relations of the plant. This feature when combined with its capability of vegetative propagation through fragments, ensures the perpetuation of weed even under drastically changed moisture conditions.

This investigation indicates that the usual practices of farmers as described earlier instead of lessening the weed helps its spread.

Summary

Drought-tolerance and drought-avoidance of the weed, *P. quadrifida* L. have been studied in the present paper. Anatomical features contributing to xerophytic nature of the weed are noted. Under sub-mortal desiccation the weed may propagate through fragments. Two conclusions have come forward as a result of this study (*i*) drought as a control measure may not be very much effective and

(*ii*) this weed is a migrant from xeric habitats where it has already secured adaptation which now fits well into the conditions of these fields.

Acknowledgements

The author wishes to express his gratitude towards Dr. L. P. Mall, The Head, School of Studies in Botany, Vikram University, Ujjain, for guidance and also for laboratory facilities.

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First Record of the Renal Fluke (*Eucotyle*) from India*

By

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[Received on 29th November, 1966]

The family Eucotylidae Skrjabin, 1924 is hitherto reported in our birds by *Tanaisia* (*Tamerlania*) *indica* Singh, 1962 which, based on a single specimen, has been described from Black-throated jay—*Garrulus lanceolatus*.

Under *Eucotyle*, with its genotype : *E. nephritica* (Mehlis in Creplin, 1846) Cohn, 1904 from *Colymous arcticus* (in Prussia), Yamaguti (1958) has listed the other five species as *E. cohni* Skrjabin, 1924, from *Podiceps nigricollis*, *P. griseigena* and *Cavia arctica* (in Russia and East Siberia) ; *E. zakharovi* Skrjabin, 1920, from *Fuligula cristata* and *Anas strepera* (in Russia) ; *E. hassalli* Price, 1930, from *Colymbus auritus* (in U. S. A.) ; *E. wehri* Price, 1930, from *Querquedula discors* (U. S. A.) ; and *E. popowi* Skrjabin *et* Evranova, 1942, from *Anas boschas* (Russia). From *Clangula hyemalis* (L) (Sweden), Walden (1960) has described *E. clangulae*. This genus remains as yet unreported in our birds.

Description

The kidney in one of the eleven specimens of the blue winged teal, *Anas querquedula*, yielded two specimens belonging to *Eucotyle*. The small-sized, thin, flattened and elongated fluke, 2·91–2·96 mm. in length and 0·51–0·58 mm. in width, carried minute cuticular spines and exhibited, in the cervical region, an ill–defined transverse groove evident from presence of clear notches on lateral margins in the oesophageal region, which appeared to mark off an anterior triangular region, of 0·53 mm. in size, from the rest of the body. The subterminal oral sucker, 0·19–0·20 × 0·14–0·22 mm in size, was followed by a somewhat prominent pharynx, of 0·027–0·053 × 0·091–0·095 mm size. The wide and 0·19–0·30 mm. long oesophagus divided, at 0·40–0·51 mm. distance behind the anterior end, into the slightly wavy intestinal caeca which, with a few small but faintly developed outgrowths/diverticulae on the medial side, exhibited a distinct bend in the testicular zone and extended to about 0·37 mm. distance in front of the posterior end. The extracaecal and symmetrically-placed testes were nearly ellipsoidal in shape and, with somewhat smooth margins, measured 0·22–0·24 × 0·08–0·15 and 0·20–0·22 × 0·08–0·12 mm. in size. Cirrus-sac was absent. The vas deferens, from each, passed forwards to enter the median and spacious but thin-walled seminal vesicle of 0·133 × 0·09 mm. size. The genital pore lay at 0·19 mm. distance behind the intestinal bifurcation. The slightly lobed but laterally placed ovary, of 0·13–0·15 × 0·10–0·14 mm. in size, lay between the seminal vesicle and the left intestinal caecum. A receptaculum seminis was absent. The two transverse vitelline ducts with the common yolk duct, the oviduct and the initial uterine coil were all visible in the shell-gland area situated just behind the ovary. The descending and ascending coils of the uterus were intercaecal and never extending laterally to the caeca, ended at

*Part of the work done, as an I.C.A.R. Senior Fellow, by S.C.S. under the guidance of B.P.P.

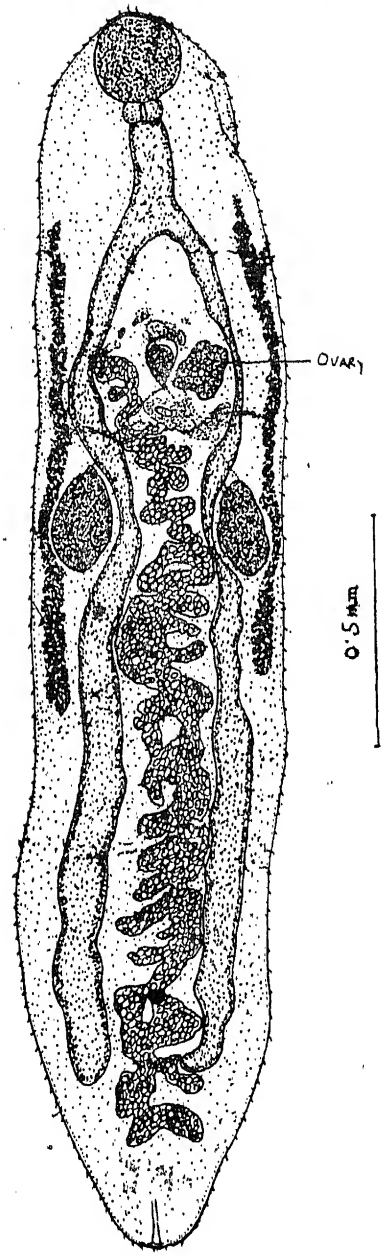

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Fig. 1. Dorsal view of *E. nephritica*.

TABLE 1

Effect of two different temperatures on growth of Cyperus rotundus L.

Growth characters	Temperature		Remarks	
	15°C	20–40°C		
No. of aerial shoots per pot	14	23	S*	1% level.
No. of leaves per aerial shoot	8	10	,,	,,
Length of longest leaf (cm)	18·2	12·2	,,	,,
Dry wt. of underground parts per pot (g)	2·15	5·05	,,	,,
Dry wt. of underground parts per pot (g)	4·0	14·20	,,	,,
No. of tubers and basal bulbs per pot	27	64	,,	,,
No. of spike bearing aerial shoots per pot	0	2	Highly significant	

S* = Difference significant at.

Plants growing outside the phytotron show higher values for all the growth characters, *viz.*, number of shoots per pot, number of leaves per aerial shoot, length of the longest leaf, dry weight of aboveground and underground parts per pot and number of tubers and basal bulbs per pot (table 1). The difference between the values for the above growth characters obtained under two different temperatures is significant even at 1% level of significance as revealed through 'T' test. None of the aerial shoots bore flowers under low temperature in phytotron while in the set kept outside the phytotron, *i.e.*, at higher temperature, there were two spike-bearing aerial shoots per pot, which means that 50 percent of the aerial shoots bore flowers. Flowering in this case started in the last week of March, 1966.

Number of tubers and basal bulbs per pot at higher temperature (20–40°C) was 64, while it was only 25 at 15°C. Reduction in number of tubers and basal bulbs at lower temperature is an interesting and useful finding in view of the significance of vegetative propagation which is quite effective means of reproduction of *C. rotundus*.

Discussion

It is evident through experimental findings that the growth of *C. rotundus* is better at higher temperature suggesting the depressive effect of low temperature on its growth.

Though this weed very heavily infests the 'Rabi' crops (winter season crops) there is little or no flowering at all during winter season. This field observation is further confirmed with the results of this experiment which indicate that the plants growing at low temperature in phytotron are devoid of flowers while those growing outside the phytotron, *i.e.*, at higher temperature (20–40°C) do flower (table 1). In view of the short duration of the experiment, it cannot, however, be said with certainty that flowering at low temperature is suppressed altogether. But the experimental results clearly indicate that flowering in the plants growing at low temperature is delayed at least by one and a half month period as compared to those growing at higher temperature.

Number of tubers and basal bulbs per pot is also far less (25) at low temperature while at higher temperature it is sufficiently high (64). No flowering at low temperature resulting in the absence of seed setting, and high reduction in population of underground propagules which are the most effective means of reproduction of *C. rotundus* suggest comparatively slow rate of spread of this weed in colder regions because of considerable decrease in reproductive capacity. This weed is regarded as more troublesome in cultivated fields of the tropics and the subtropics (Andrews, 1940), which may be due to enhanced growth, profuse flowering resulting in high seed output and augmented population of underground tubers at higher temperature. The possibility of more reduction in tuber population under still lower temperature cannot be ruled out. Further experimentation on temperature relations of *C. rotundus* is needed before any concrete conclusion can be drawn in this respect.

Conclusions

The plants of *C. rotundus* growing at low temperature (15°C) show poorer growth than those growing at higher temperature (20–40°C). The growth characters such as number of aerial shoots per pot, number of leaves per aerial shoot, length of the longest leaf, dry weight of aboveground and underground parts per pot show significantly high values at higher temperature (20 40°C).

At 15°C no flowering took place during the period of three and half months, while the plants growing outside the phytotron (at higher temperature) bore flowers.

Production of tubers and basal bulbs per pot is also highly reduced at low temperature.

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Ecology of *Cyperus rotundus* L. V. Reproduction by seeds

By

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[Received on 25th January, 1968]

Introduction

Cyperus rotundus L. mainly propagates through tubers and basal bulbs, and the reproduction by seeds is relatively unimportant (Smith and Fick, 1957; Andrews, 1940 ; Justice, 1946). Smith and Fick (1937) observed that this weed flowers regularly but they could not get the seeds in the vicinity of Alabama. Holcomb (1940) reported a high degree of sterility in *C. rotundus* and failed to find viable seeds. However, some workers (Muenscher, 1935 ; Pillay, 1944) attached importance to seeds in reproduction. Under Indian conditions, the weed has been reported to set sufficiently high number of seeds (Ranade and Burns, 1925; Mall and Shukla, 1965). Ranade and Burns (1925) found considerably high percentage of germination while Mall and Shukla (1965) failed to get seed germination. In view of the contradictory reports regarding the production of viable seeds and the part played by seeds in propagation of this weed, it was thought worthwhile to investigate whether the plants of *C. rotundus* growing in and around Varanasi (25°.2′ North latitude and 83°.0′ East longitude) produce seeds and whether the seeds are capable of germination.

Experimental procedure and results

Seed output : Though *C. rotundus* plants may be seen flowering and fruiting all the year round, there are two main flowering and fruiting periods, *viz.*, February to May and July to October, and as such this weeds sets two crops of seed in a year. In order to determine the average number of seed produced per aerial shoot of this weed, a number of inflorescences in which seed setting was complete, were collected and the seeds born on them were counted. The first collection was made on 17th May, 1965 from a wheat field of Banaras Hindu University and the second on 6th November, 1965 from the open non-cultivated ground of Botany department. The seeds per aerial shoot were counted separately for the two lots and the results are set in tables 1 and 2. It may be noted here that most of the aerial shoots which apparently look as separate plants, are connected to one another through underground network of tubers and rhizomes, and the delimitation of individual plants of *C. rotundus* is very difficult. Therefore, the data presented here will correspond to seed output per aerial shoot.

The average number of seeds produced by one aerial shoot in November is 258, with a wide range of 1–900.

The data set in Table 2 indicate that most of the individuals fall in frequency classes 2, 3 and 4.

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TABLE 1

Seed output per aerial shoot of C. rotundus L. *collected in the month of May,* 1965.
(Number of aerial shoots counted for determining seed output=15)

No. of seeds per aerial shoot	No. of aerial shoots	No. of seeds per aerial shoot	No. of aerial shoots
45	1	164	1
59	1	180	1
108	1	190	1
113	1	196	1
126	1	277	1
132	1	278	1
134	1	280	1
		297	1

The average seed output in May is 172, the range being 45–297.

TABLE 2

Seed output per aerial shoot of C. rotundus L. *collected in the month of November,* 19
(Number of aerial shoots counted for determining seed output=100).

No. of seeds per aerial shoot	No. of aerial shoots	Frequency class
1–100	7	1
101–200	30	2
201–300	28	3
301–400	23	4
401–500	7	5
501–600	3	6
601–700	1	7
701–800	0	8
801–900	1	9

It is clear from the above tables that the seed output per aerial shoot of *C. rotundus* is sufficiently high. In view of the high infestation of this weed, seed production in this magnitude is quite alarming.

Seed germination : Seeds collected from agricultural farm of Banaras Hindu University on 17th May, 1965 were stored in corked bottles at 30–35°C, and were tested for germination at 20°C, 30°C and 40°C in June (between 6th and 26th June) and in August (between 9th and 29th August) of 1965. Germination tests in all the cases were made by putting seeds in between two moist filter papers in Petri dishes.

TABLE 3

Germination of the seeds of C. rotundus L. *collected on 17th May*, 1965

Test period	*Percentage germination at 20°C	30°C	40°C
June	0	16	0
August	0	51	0

*Average of two replicates of 50 seeds each.

Data contained in table 3 reveal that the optimum temperature for germination of the seeds of *C. rotundus* is 30°C, and that seeds fail to germinate at 20° and 40°C. Fresh seeds show 16% germination at 30°C. Germinability of the seeds, however, increases with storage period.

Seeds collected on 6th November, 1965 were tested for germination in November/December (from 29th November to 31st December, 1965) and in March (from 2nd March to 9th April, 1965) at 20°, 30° and 40°C. In the month of March, germination was also tried at daily alternating temperatures of 20° to 40°C (7 hrs. to 17 hrs.) and 40° to 30°C (7 hrs. to 17hrs.). The results are shown in table 4.

TABLE 4

Germination of C. rotundus L. *seeds collected in the month of November*, 1965

Test period	*Percentage germination at 20°C	30°C	40°C	30–40°C (7 to 17 hrs)	40–30°C (7o 17 hrs.)
Nov./Dec.	0	1·6	·3	–	–
March/April	–	2·3	·3	·6	1·3

*Values represent the average of 3 replicates with 100 seeds each.

In the case of seeds collected in November, 1965 the percentage germination is very low as compared to those collected in May (compare tables 3 and 4). Here also, 30°C appears to be favourable temperature for germination (*see* table 4).

Effect of Scarification : The seed collected in November, 1965 were treated with normal sulphuric acid for 5, 10, 15, 20 and 25 minutes on 15th April, 1966, and were kept for germination at 30°C. Side by side one set with non-scarified seed was also kept for comparison. The experiment was continued upto 10th May, 1966. The results are shown in table 5.

TABLE 5

Effect of scarification on percentage germination of the seeds of C. rotundus L.

	Non scarified seeds	Seeds scarified with H_2SO_4 for 5 mts.	10 mts.	15 mts.	20 mts.	25 mts.
*Percentage germination	2	2·6	9·3	26	21·3	2·3

*Average of 3 replicates with 100 seeds each.

Data set in table 5 reveal that scarification helps in seed germination, which implies that low germinability of the seeds of *C. rotundus*, at least in part, is due to hard covering around the seed.

Discussion

According to Smith and Fick (1937), mature seeds are not found in *Cyperus rotundus* and Holcumb (1940) reported a very high degree of sterility in this weed. The present study which reveals that the seed output per aerial shoot of *C. rotundus* is very high, does not lend support to the views of Smith and Fick (1937) and Holcomb (1940). High seed output per aerial shoot when considerd in terms of severe infestation of this weed (Tripathi, 1965) will definitely result in very large figure. Ranade and Burns (1925) through calculations have shown that in a moderately infested field at least 53,9,00,000 seeds of *C. rotundus* per acre, are added to the field every year. Further, the germination studies indicate that the seeds collected in May give 16% germination at 30°C in June and the same after about three months storage show 51% germination. The seeds collected in Nov., 1965 when tested for germination in April, 1966, after scarification with normal sulphuric acid for 15 minutes give 26% germination. Ranade and Burns (1925) also found a high percentage of germination (24% in case of fresh seeds and 80% after four months storage). Mall and Shukla (1965) found 40% seeds of *C. rotundus* growing around Ujjain (India) to be viable but seed germination could not be observed by them even after a number of different treatments including mechanical and acid scarification for 12 minutes. At least under Indian conditions as is evident by the experimental results, the author feels that the seeds of *C. rotundus* have considerably high potential for germination and may serve as an effective means of propagation of this weed. In order to minimize the weed infestation, therefore, it is suggested that the weed must not be allowed to set seeds.

The germination behaviour of seeds collected in the month of November differs from those collected in May, for which no reason at present could be attributed.

Conclusions

There are mainly two flowering and fruiting periods of *C. rotundus*, viz., February to May and July to October. The average seed output per aerial shoot is 172 in May and 258 in November. Germination tests indicate that optimum temperature for the germination of *C. rotundus* seeds is 30°C (tables 3 and 4). Fresh seeds of *C. rotundus* may also germinate and the germinability increases with storage period.

The seeds collected in November show very poor germination as compared to those collected in May. The effect of scarification on germination is quite marked. The seeds scarified with normal sulphuric acid for 15 minutes show 26% germination while the non-scarified ones show only 2% germination.

The data regarding high seed output per aerial shoot, and germinability of the seeds of *C. rotundus* reveal that seeds play an important role in propagation of this weed.

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On the Endosternite of the Scorpion Heterometrus sp. and the associated muscles

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The endosternite of scorpion, situated in the cephalothoracic region, is the principle median endoskeletal structure. It is not fixed to any of the chitinous skeletal pieces, except by muscles and fibrous tissue (Lankester *et al.* 1885). However posteriorly it fuses with a septum which is generally known as diaphragm. The diaphragm separates the prosomatic part of the body cavity from the mesosomatic one. As stated by Bernard (1894), this fusion with the diaphragm has made the structure of the endosternite more complicated. Based on the histological studies of the endosternite and the diaphragm of the scorpion, *Buthus tamulus* (Fabr), Awati and Tembe (1956) state that both these structures are distinctly separate and that the endosternite is derived from apodemes whereas the diaphragm is the product of the chitinisation of the infolded intersegmental arthrodial membrane between seventh and eighth segments.

As has been described by number of authorities including Lankester *et al.* (1885), Parker and Haswell (1949), Awati and Tembe (1956) etc., the main role of the endosternite is to offer strong attachment for the muscles effecting movements of the appendages, the carapace and the genital operculum. The present attempt has been made therefore to study the structural aspects of the endosternite in details and the functional role of the endosternite and the associated muscles in the scorpion, Heterometrus sp.

Materials and Method

Live scorpions were collected from the fields situated round about the Gujarat University Compus at Ahmedabad and were kept alive in the laboratory under situable conditions for observations. The skeletal preparations were made by boiling the scorpions in 5% KOH solution after removing the carapace and the muscles. The dissections were done in the normal saline solution for arachnids with the aid of a stereomicroscope binocular dissecting microscope. The mechanism of the movements of the appendages and the other parts were observed carefully with the naked eyes and also under the binocular dissecting microscope. Various muscles attached with the endosternite were stimulated by an electric current with the help of a 9 Volts electrically operated energiser.

To avoid confusion, in naming the various parts of the endosternite and associated muscles, the terminology adopted by Lankester *et al.* (1885) is used as far as possible.

Observations

The Endosternite (Plastron) : (Fig. 1).

The endosternite consists of a main body which is perforated in the centre and number of processes which radiate in different directions. The body is situated between the posterior coxal entosclerites of the fourth and fifth appendages and made up of a compact mass of whitish connective tissue. The nerve cord and the ventral longitudinal muscles pass through the central perforation. There are in all nine processes of which four arise in pairs. All the processes serve for the attachment of the various muscles operating the movements of the appendages, the carapace and the other parts of the body. These processes have been named as follows :

A. Paired processes :

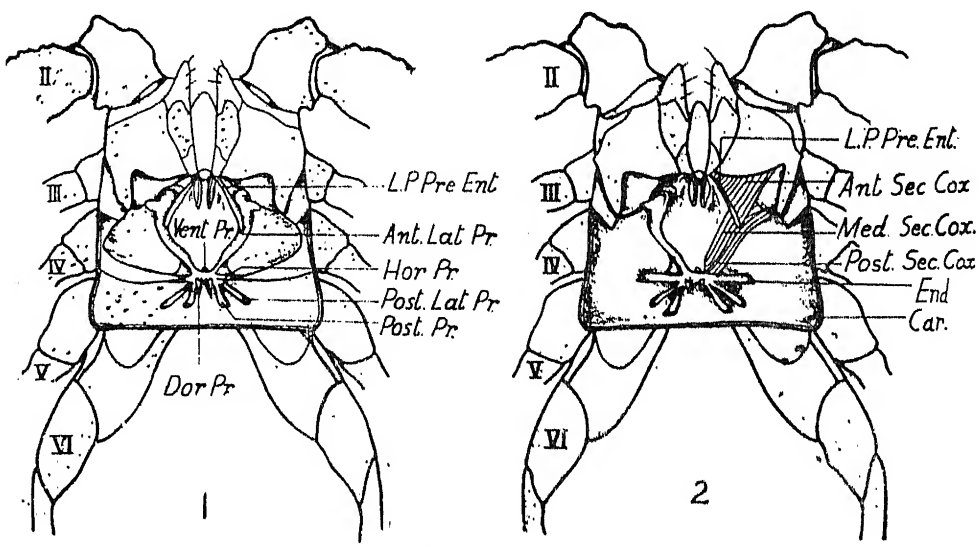
1. Dorsal processes
2. Antero-lateral processes
3. Horizontal processes
4. Postero-lateral processes
5. Posterior processes

B. Unpaired process :

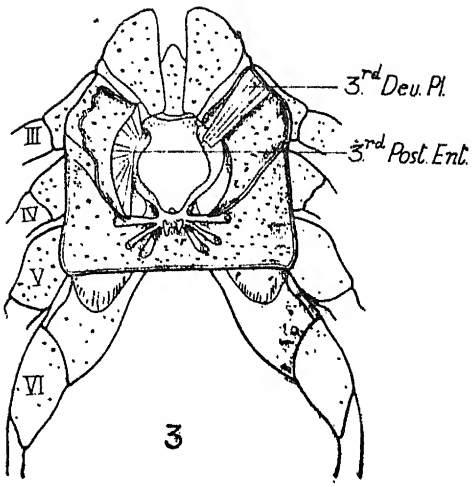
6. Ventral process

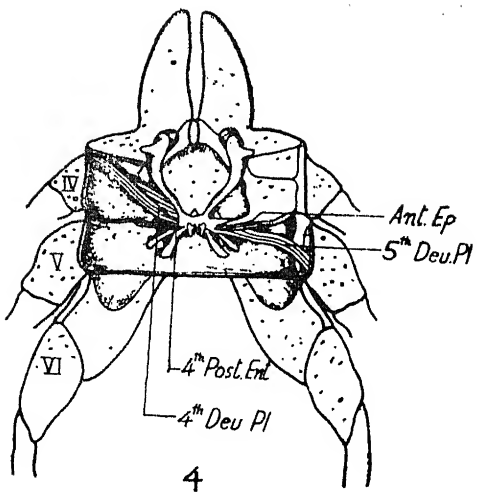
1. *Dorsal processes* : These processes are small and less prominent. Each of them arises laterally from the dorsal wall. The anterior part of the processes serves for the attachment of the dorso-plastron muscles whereas posteriorly it is fused with the adjoining diaphragm.

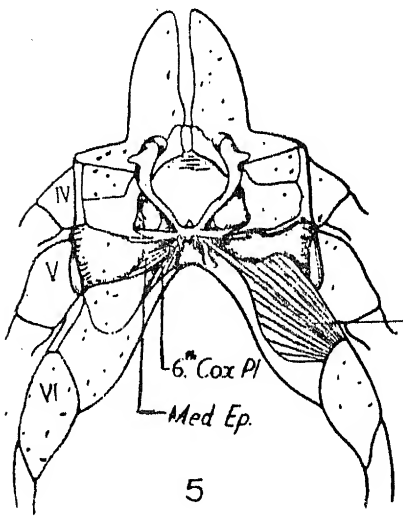
2. *Antero-lateral processes* : These processes are very prominent and arise from the antero-lateral margins of the dorsal wall and are directed forwards. Each

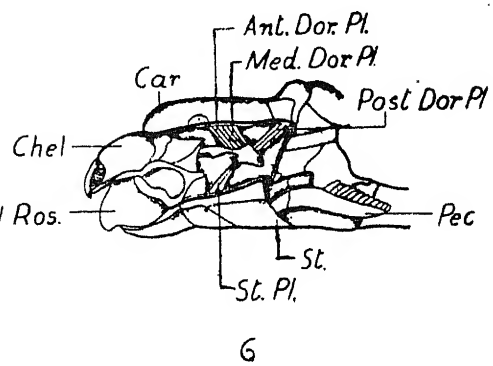


1. Endosternite and its various processes. 2. Plastron muscles of pedipalp.









3, 4, and 5.—Plastron muscles of the walking legs.

6. Dorso-plastron and sterno-plastron muscles.

ABBREVIATIONS

II—Pedipalp; III–VI—Walking legs; Ant.Dor.Pl.—Anterior dorso-plastron muscle; Ant.Ep.—Anterior epimeron-plastron muscle; Ant.Lat.Pr.—Antero-lateral process; Ant.Sec. Cox.—Anterior second coxo-plastron muscle; Car.—Carapace; Chel.—Chelicera; Cox.-Pl. Coxo-plastron muscle; Deu.Pl.—Deutomerite-plastron muscle; Dor.Pr.—Dorsal process; End. —endosternite; Hor.Pr.—Horizontal process; L.P.Pre.Ent.—Lateral process of preoral entosclerite; Med.Ep.—Median epimeron plastron muscle; Med.Dor.Pl.—Median dorso-plastron muscle; Med.Sec.Cox.—Median second coxo-plastron muscle; Pec.—Pectine; Post.Dor.Pl.—Posterior dorso-plastron muscle; Post.Ent.—Posterior margin of entosclerite; Post.Lat.Pr.—Postero-lateral process; Post.Pr.—Posterior process; Post.Sec.Cox.—Posterior second coxo-plastron muscle; Ros.—Rostrum; St.—Sternum; St.Pl.—Sterno-plastron muscle; Vent. Pr.—Ventral process.

process extends anteriorly upto the base of the coxa of the pedipalp and is provided with a flat tendinous flap at its end.

3. *Horizontal processes* : The horizontal processes which are also known as transverse processes, run from the lateral walls of the endosternite to the coxal-entosclerite of the fourth appendages. They are broad and flat.

4. *Posterior processes* : These paired processes arise from the posterior wall of the endosternite ring. The processes appear less prominent than the other ones, as most of their major portion remains fused with the adjoining diaphragm.

5. *Postero-lateral processes* : These process are generally termed as posterior processes. But at such each of them arises from the angle between the horizontal and posterior processes and runs in the postero-lateral direction, towards the base of the sixth coxa. Their distal ends, like those of the posterior ones, remain fused with the diaphragm.

6. *Ventral process* : This poorly developed, single process arises from the mid-ventral part of the main body and runs forwards for a short distance. Its distal end bears a pair of tendinous processes which provide an attachment for the sterno-plastron muscles.

Plastron Muscles

The plastron muscles arise from the various regions of the endosternite and can be divided into following main catagories :

I. Muscles associated with the pedipalps and the walking legs.
II. Dorso-plastron (Tergal) muscles.
III. Sterno-plastron (Ventral) muscles.
IV. Muscles associated with the genital operculum and the pectinal appendages. (These muscles however are not included here as they form a separate series of muscles not involving movements of the appendages).

I. *Muscles associated with the pedipalps and walking legs* : These comprise coxo-plastron, coxal entosclerite-plastron and deutomerite plastron muscles of the appendages. All of these arise from the plastron (endosternite) and are variously inserted. They comprise the following series of muscles :

1. The median second coxo-plastron muscle
2. The posterior second coxo-plastron muscle
3. The third deutomerite-plastron muscle
4. The third postcoxal entosclerite-plastron muscle
5. The fourth deutomerite-plastron muscle
6. The fourth postcoxal entosclerite-plastron muscle
7. The anterior epimeron-plastron muscle
8. The fifth deutomerite-plastron muscle
9. The median epimeron-plastron muscle
10. The sixth deutomerite-plastron muscle
11. The sixth coxo-plastron muscle.

The Median second coxo-plastron muscle : (Fig. 2).

This is a flat strap shaped muscle, obliquely situated in between the proximal part of the anterior process and the base of the coxa of the pedipalp. It shows a parallel pattern of fibre arrangement.

Origin : The muscle arises in a broad and fleshy origin from the inner-dorsal margin of the antero-lateral process.

Insertion : It runs forwards and outwards to gain a fleshy insertion onthe mid–ventral part of the base of the coxa.

Action : It serves as a promotor of the coxal segment and its contraction results in a forward movement of the pedipalp.

The posterior second coxo–plastron muscle : (Fig. 2).

This muscle is broader than its median counterpart with which it is closely associated externally. This muscle also presents a parallel fibre arrangement.

Origin : The muscle arises in a broad and fleshy origin from the antero–lateral process behind that of its median counterpart.

Insertion : It gains a broad and fleshy insertion on the outer–ventral wall of the base of the coxa of the pedipalp.

Action : This muscle by contraction, serves as a remotor of the second coxa whereby the pedipalp moves backwards.

The third deutomerite–plastron muscle : (Fig. 3).

The muscle is situated between the antero–lateral process and the base of the trochanter of the third appendage. Towards the origin it is covered by the muscles described earlier. This muscle presents parallel arrangement of fibres.

Origin : It arises tendinously from the lateral tendinous projection of the antero–lateral process.

Insertion : The muscle passes through the third coxa and gains insertion on the inner–anterior margin of the base of the third trochanter.

Action : The muscle serves as a depressor of the trochanter and its contraction results in a forward movement of the third appendage.

The third postcoxal entosclerite–plastron muscle : (Fig. 3).

This is a fan shaped muscle situated in between the coxal entosclerite of the third appendage and the endosternite. Proximally, it remains covered by the plastron muscles of the pedipalp and its deutomerite counterpart. The muscle shows a parallel type of fibre arrangement.

Origin : It arises tendinously from the antero–lateral process, ventral to the origin of its counterpart.

Insertion : The muscle becomes broader as it moves forward from the origin and gains a partly fleshy and partly tendinous insertion on the entire interior margin of the third coxal entosclerite.

Action : It serve as a levator of the coxa and brings about a backward movement of the third appendage.

The fourth deutomerite–plastron muscle : (Fig. 4).

This is a well developed long muscle which is situated in between the horizontal process and the anterior part of the base of the trochanter of the fourth appendage. The muscle takes a bend by about 60° on its way to insertion and its fibres form parallel type of arrangement.

Origin : The muscle arises in a tendinous origin from the angle between the antero–lateral and horizontal processes.

Insertion : It gains a narrow and tendinous insertion on the anterior margin of the base of the trochanter.

Action : It serve as a depressor of the fourth trochanter and brings about a forward movement of the fourth appendage.

The Fourth postcoxal entosclerite-plastron muscle : (Fig. 4).

This muscle is feebly developed and is situated between the horizontal process and the inner margin of the posterior coxal entosclerite of the fourth appendage. The muscle shows parallel arrangement of fibres.

Origin : It arises in a broad and fleshy origin from the outer end of the horizontal process.

Insertion : The muscle inserts fleshily on the exterior margin of the fourth coxal entosclerite.

Action : The muscle serves as an opposite member to its deutomerite counterpart. The contraction of this muscle results in a backward movement of the fourth appendage.

The Anterior epimeron plastron muscle (Fig. 4).

This ribbon shaped muscle is situated between the postero-lateral process of the plastron and the fifth coxa. It runs parallel to the arthrodial membrane connecting the coxae of the fourth and fifth appendages. It presents a parallel pattern of fibre arrangement.

Origin : The muscle arises tendinously in a narrow origin from the proximal end of the postero-lateral process behind the origin of the fourth postcoxal entosclerite-plastron muscle.

Insertion : The muscle gains a tendinous insertion on the arthrodial membrane joining the fourth and fifth coxal segments.

Action : By contraction of this muscle, the fifth coxa is raised up.

The Fifth deutomerite-plastron muscle (Fig. 4)..

This muscle is similar to its fourth deutomerite counterpart. It is situated inbetween the postero-lateral process and the trochanter of the fifth appendage and occupies a larger space of the coxa through which it passes. It presents a parallel pattern of fibre arrangement.

Origin : The muscle arises fleshily from the postero-lateral process behind the origin of the anterior epimeron-plastron muscle.

Insertion : It gains a narrow and tendinous insertion towards the interior margin of the posterior part of the base of the trochanter.

Action : The muscle serves as a depressor of the trochanter and brings about a forward movement of the fifth appendage.

The Median epimeron-plastron muscle : (Fig. 5).

This is a small muscle situated inbetween the endosternite and the coxae of the fifth and sixth appendages. It presents a parallel arrangement of the fibres.

Origin : The muscle arises from the proximal part of the postero-lateral process in a narrow and tendinous origin.

Insertion : It runs parallel to the postero-lateral process for a short distance and becomes fan shaped towards the insertion. The muscle inserts partly fleshily and partly tendinously on the arthrodial membrane connecting the fifth and sixth coxae.

Action : The muscle works as a levator of the sixth coxa and its contraction results in a backward movement of the sixth leg.

The Sixth deutomerite–plastron muscle : (Fig. 5).

This large massive muscle is situated between the postero–lateral process and the trochanter of the sixth appendage. Practically it occupies the entire cavity of the sixth coxa. The muscle presents a parallel pattern of fibre arrangement.

Origin : The muscle arises in a broad and fleshy origin. Most of its fibres arise from the inner walls of the coxa. However, some fibres arise from the ventral part of the postero–lateral process of the endosternite.

Insertion : It gains a tendinous insertion on the interior margin of the anterior basal part of the trochanter.

Action : The muscle serves as a depressor of the trochanter and its action brings about a forward movement of the sixth appendage.

The Sixth coxo–plastron muscle : (Fig. 5).

The muscle is situated between the postero–lateral process and the sixth coxa. It is partly covered by the diaphragm and partly by some of the plastron muscles of the fifth and sixth legs.

Origin : It arises in a narrow and tendinous origin from the ventral proximal part of the postero–lateral process.

Insertion : The muscle inserts tendinously on the proximal part of the posterior margin of the sixth coxa.

Action : It brings about a backward movement of the sixth appendage and like its median counterpart helps in the raising up of the sixth coxa.

II. *Dorso–plastron muscle (Tergal muscles)* : (Fig. 6).

The dorso-plastron muscles include the muscles situated between the plastron and the dorsal exoskeletal plates. The series comprises (1) Anterior (2) Median and (3) Posterior dorso–plastron muscles.

The Anterior dorso–plastron muscle : (Fig. 6).

This muscle consists of two slips towards the origin and is situated inbetween the antero–lateral sides of the carapace behind the median eyes and the dorsal processes. The muscle fibres of both the slips show parallel arrangement.

Origin : Each of these slips arises tendinously in a broad origin from the dorsal process of the endosternite.

Insertion : As the two slips run forwards become united in the middle so as to form a single unit which inserts fleshily on the inner walls of the carapace behind the median eyes.

The Median dorso–plastron muscle : (Fig. 6).

It is situated behind its anterior counterpart. It presents a parallel pattern of fibre arrangement.

Origin : The muscle arises in a narrow and tendinous origin from the dorsal process behind the orgin of its anterior counterpart.

Insertion : It gains a broad and fleshy insertion on the inner wall of the carapace behind its anterior fellow.

The Posterior dorso–plastron muscle : (Fig. 6).

This is a well developed muscle located inbetween the dorsal process and the first tergum of the mesosoma. It shows a parallel type of fibre arrangement.

Origin : The muscle arises in a narrow and tendinous origin from the dorsal process.

Insertion : It runs for a short distance on the anterior surface of the diaphragm through which it passes later on and gains a broad and fleshy insertion on the inner wall of the first mesosomatic tergum.

Action : The contraction of these muscles results in the reduction of the capacity of the cephalo–thoracic cavity.

III. *The Sterno–plastron (Ventral) muscles* :

These muscles are represented by a single pair only and are termed as sterno subneural–plastron muscles.

The sterno subneural–plastron muscle :

This muscle is small and is situated between the ventral process and the metasternite.

Origin : It arises in a narrow tendinous origin from the ventral process.

Insertion : The muscle gains a broad tendinous insertion on the anterior margin of the metasternite behind the postoral entosclerite.

Action : The contraction of this muscle brings about a reduction of the cephalo–thoracic cavity by raising the sternal plate.

Discussion

The fusion of the diaphragm with the endosternite in scorpions has lead various workers in the past to believe these structures as parts of a composite organ. Lankester *et al.* (1885) considered the diphragm to be a posterior flap of the prosomatic entochondrite (endosternite). It was Bernard (1894), who described it as a separate structure. Later on Awati and Tembe (1956), based on the histological studies, stated that the endosternite has derived from the apodems whereas the diaphragm is formed by the chitinisation of the inter–segmental arthrodial membrane. The validity of this statement can be easily ascertained by observing a freshly prepared skeleton. On dehydration, the endosternite and its various processes separate from the diaphragm.

The structure of the endosternite of the different species of scorpion has been described by various authors (Lankester *et al.* 1885, in Scorpio ; Pocock (as mentioned by Prasad, 1964) in Lurus ; Awati and Tembe 1956, in Buthus) in the past. The present studies revealed certain additional features which have not been described earlier and it has been considered desirable to review the structure of the plastron in light of these observations.

In the posterior region of the endosternite, only one pair of processes has been so for recorded and termed as posterior processes by the earlier workers. Our observations in Heterometrus show that actually there are two pairs of processes in this region. Based on their location these processes are termed here as postero–lateral and posterior processes respectively.

Similarly in the dorsal region, a pair of processes, not hitherto described have also been observed. These are termed here as dorsal processes as they are situated dorsally.

As regards the muscles associated with the endosternite of the sporpion, the only work available is that of Lankester *et al.* (1885) who have given a brief description of these muscles in Scorpio. The present work gives a more detailed account of their gross anatomy. The following noteworthy differences were observed between the muscles of Heterometrus and those of Scorpio described by Lankester *et al.* (1885).

1. The anterior second coxo–plastron muscle as observed in Scorpio, arises from the anterior process of the endosternite. But in Heterometrus, this muscle takes its origin from the lateral process of the preoral entosclerite.

2. The major portion of the sixth deutomerite-plastron muscle in Heterometrus, arises from the inner wall of the sixth coxa. However, some fibres seem to arise from the ventral part of the endosternite also.

3. The posterior epimeron–plastron muscle is not present.

Summary and Conclusions

The study deals with the structure of the endosternite and its associated muscles in the scorpion Heterometrus sp.

1. The endosternite consists of main body and processes radiating from it to various directions. These are known as dorsal, antero–lateral, horizontal, postero–lateral, posterior and ventral processes.

2. The posterior and dorsal processes are described for the first time.

3. The anterior second coxo–plastron muscle does not seem to arise from the endosternite but it arises from the preoral entosclerite.

4. The posterior epimeron–plastron muscle described by Lankester is not observed here.

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Studies on Ecotypes and Ecads of *Mecardonia dianthera* III. Ecological distribution, phenology, dispersal and stomata

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In the previous papers of this series, significant differences exhibited by the ecads and ecotypes of *M. dianthera* in seeds germination pattern, storage behaviour, reproductive and aggressive capacity have been brought out (Kaul, 1967*b*, *c*,). The present paper throws light upon the ecological distribution, dispersal mechanism, phenology and stomatal apparatus of the ecads and ecotypes of the plant.

Methods of the study are the same as reported in the previous publications (1967*a*).

Observations

Ecological distribution

Mecardonia dianthera is a native to tropical America (Mooney 1950, Srivastava, 1964) and is a recent introduction to India. The first report of its occurrence was made by Prain in 1903 from Bengal. Since then it has been detected in Assam (Chatterjee, 1948), Bihar (Benthal, 1950), Ranchi (Bressers, 1951), Dehra Dun (Raizada, 1951), Banaras (Chatterjee and Bharadhawaja, 1955). The species has spread both eastwards and westwards in India very quickly (Mooney, 1950).

In Varanasi and its adjacent areas, natural population of *M. dianthera* occur abundantly in damp regions, in cultivated fields, lawns and gardens, along drains and drainage channels, stream banks; in neglected garden and backyards of houses; along river banks, brooks and nallahs; in swampy areas; on roads and foot paths. In all these places, the plant occurs under shady places (Figs. 1–2. Along the moist banks of water channels and the pools of standing water, it is seen occurring in continuous stands of linear populations as well as in the form of spreading patches. It is abundant in sites that are very wet and shady, the clear case being of its great abundance in depressions and beds of water channels. It is also of a frequent occurrence along the margin of pools, puddles and canal banks between clumps of mosses.

In *Mecardonia dianthera*, two ecotypes, *viz.*, erect and repent have been detected by the present worker to be growing wild in nature (Kaul, 1965). The erect ecotype is confined to moist shady habitats, protected areas, cultivated fields, gardens and lawns with neutral or slightly basic soils (Kaul, 1965, 1967*a*). The repent ecotype grows in moist shady as well as in comparatively drier, hard slightly acidic or neutral soils exposed to trampling, *i.e.* along foot paths and other such places. (Kaul, 1965).

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Gregariousness

Both the erect and repent ecotypes of *M. dianthera* are gregarious in nature and form pure stands of their own. Very often plants like *Scoparia dulcis, Vandelia crustacea, Ageratum conyzoides, Oxalis acetocella. Blumea* sp. grow side by side with them without any detrimental effect. The plants of repent ecotype are scattered and form patches along road sides and foot paths. The populations of extreme density occur in the Botanical garden (B. H. U.), and in Sarnath under shade of *Ficus* trees. Here the plants of repent ecotype have spread much more quickly than usual. They coalesce producing a more or less complete cover. On the fringes of these populations where the shade is lacking, the plants are much more scattered.

Phenology

The phenology of the two ecotypes of *M. dianthera* as observed at Varanasi and its adjacent areas is slightly different and is presented separately.

Repent ecotype : A few seedlings make their appearance on moist and shady habitat in late March and April. But majority of these (86%) appear from late July to August, when the soil is wet (due to frequently abundant rains) and temperature is comparatively high (Temp. 33·2°C, rainfall = 278·2 m.m. ; *See* Kaul, 1965). After light winter showers in late November stray seedlings have been observed which develop feebly but perish with the onset of December.

The plant produces first flower when it is only 21–27 days old but continues vegetative growth along with flowering and fruiting for 57 to 68 days. In nature, it flowers from September to October. The plants completely vanish in the month of December.

Erect ecotype : The seedlings of the erect ecotype appear in wet and shady places in the first week of August. The plant develops first flowers when it is 21–25 days old. It continues vegetative and reproductive growth for 47 to 56 days. Since the first formed flowers are produced laterally, the vegetative growth is continued by the terminal bud. After 47–56 days of growth, the vegetative growth comes to an end. After maturity as soon as the seeds fall on the soil, they germinate successfully in favourable places for there is no dormancy in seeds (Kaul, 1965, 1967 *a*, *b*). The plants formed thereof grow, flower and fruit as usual. But the seedlings of erect ecotype are seen only upto the 2nd week of October, after which the mature plants as well as the seedlings perish. In the second week of November, no trace of the plants can be seen at Varanasi and its adjacent areas.

Dispersal mechanism

The floral structure and the mechanism of dispersal of both the ecotypes are similar. The capsule is 2–valved and is shorter than the calyx which surrounds it wholly. It opens as the two valves separate septicidally from the placentiferous dissepiment, exposing numerous, minutes and ovate seeds. At no time birds or other animals have been observed feeding on the seeds which would presumably favour their dissemination. The seeds are very light, weighing 0·012 mg. and possess no special apparatus for dispersal. They are merely blown away by wind because of their extreme lightness. Such types seeds have been classified as 'dust or powder' seeds by Ridley (1930).

The plants have been found growing along the margin of pools, puddles, drainage channels in between clumps of mosses etc. Moreover, the seeds float for 7–9 hours in water and germinate thereafter quite successfully. Hence, it seems that water currents may be important factors in its seed dispersal. The plant is

found to be growing in certain depressions which are so formed that the drainage water enters on one side and leaves from the eroded area on the other side. Often the plants grow more densely on the side where water enters showing an accumulation of seeds there due to water currents. However, the seeds may be carried also by rain washes to long distances.

Environmental Factors

Climatic factor : The plant cannot withstand extreme low temperature prevalent in December-February, so dies away in these months. It does not grow on places exposed to direct sunlight. Hence, it seems to be a shady mesophyte.

Edaphic factor : The edaphic factors concerning calcicolous calcifugous habit of this plant have been analysed (Kaul, 1965, 1967*a*). From the study it has been concluded that while erect ecotype of the plant is a facultative calcicole, the repent ecotype is an obligate calcifuge (Kaul, 1967*a*).

Biotic factor : The plants withstand grazing by cattle and scraping by man. The repent forms that grow on foot paths withstand trampling by becoming compact and reduced. They are eliminated from the calcareous soil by interspecific competition in addition to seedling mortality. No fungal parasites attacking the plant could be found presently nor seem to have been reported so far.

Stromatal Apparatus

The epidermal cells of the leaves of *M. dianthera* are wavey in outline on both the surfaces of leaf, in erect and repent ecotype (Fig. 3). The leaves are amphistomatal. The guard cells of fully developed stomata are on an average 29·1μ × 20·9μ in size, the stomatal pore being 10·6μ × 6·1μ, when wide open. The stomata are of anomocytic (Ranuculus) type, in both the ecotypes of *M. dianthera* (Fig. 3). The stomatal frequency and stomatal index are higher on the dorsal surface than on the ventral surface of the leaf (Table I). There is a sharp decreasing gradient of stomatal frequency from tip to the base, on both the surfaces of the leaf. This gredient is not so sharp for stomatal index (Table I).

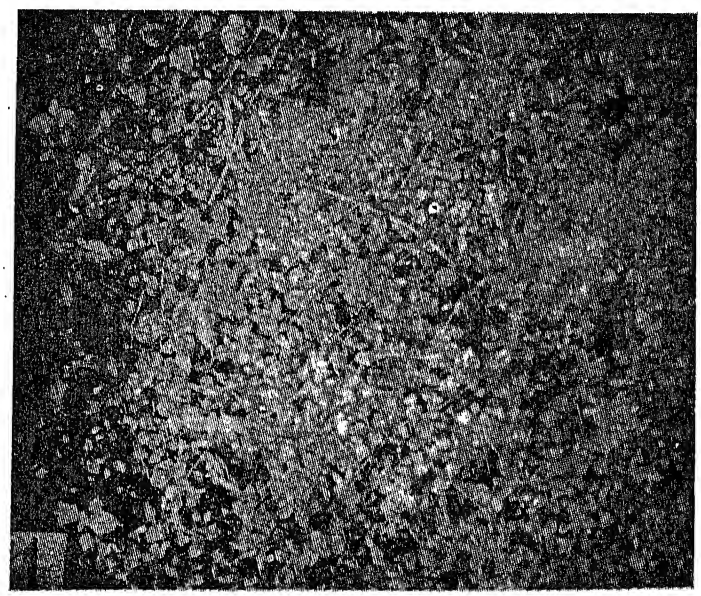

Fig. 1. Repent ecotype in moist and shady habitats × 1/15.

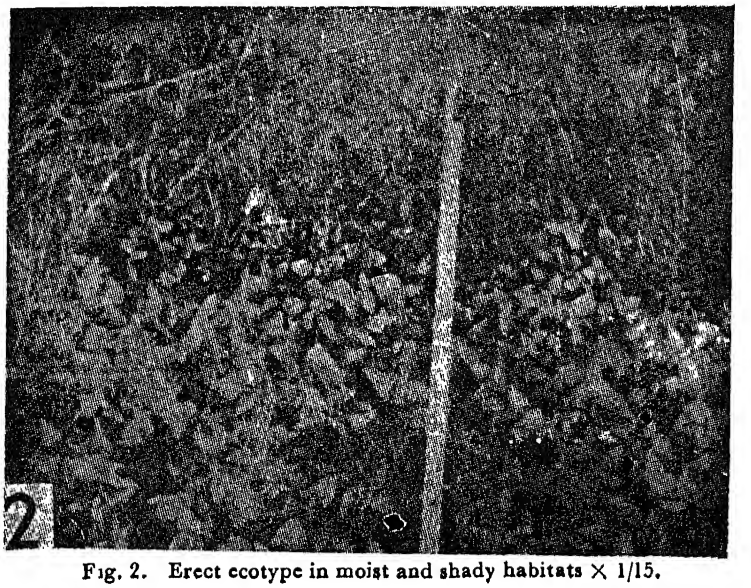

Fig. 2. Erect ecotype in moist and shady habitats × 1/15.

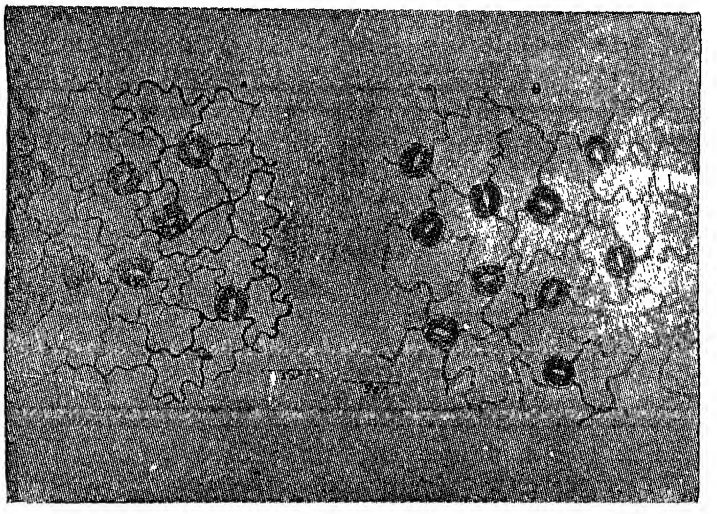

Fig. 3. Stomata of the leaves of the erect (A) and repent (B) ecotype.

TABLE I

Stomatal Study of M. dianthera. (*Mean values of 40 leave of 3rd node*)

Plants form	Stomatal frequency/sq.mm						Stomatal index					
	Dorsal surface			Ventral surface			Dorsal surface			Ventral surface		
	Tip	Middle	Base	Tip	Middle	Base	Tip	Middle	Base	Tip	Middle	Base
Normal repent (in nature)	293 ± 12	242 ± 7	178 ± 4	229 ± 9	163 ± 6	127 ± 3	37·7 ± 0·3	37·5 ± 0·6	37·4 ± 0·8	29·8 ± 1·1	29·4 ± 0·9	28·7 ± 0·9
Compact repent (in nature)	408 ± 14	339 ± 5	242 ± 7	281 ± 4	216 ± 6	163 ± 3	38·3 ± 0·8	38·3 ± 0·9	38·1 ± 0·9	31·5 ± 1·2	31·1 ± 1·1	30·6 ± 0·7
Compact repent (in culture)	301 ± 24	257 ± 8	193 ± 15	237 ± 6	170 ± 7	141 ± 4	37·9 ± 1·2	37·6 ± 0·9	37·1 ± 1·3	30·1 ± 1·0	29·7 ± 0·9	29·5 ± 0·9
Erect form (in nature)	241 ± 9	223 ± 6	211 ± 9	234 ± 8	226 ± 7	215 ± 3	36·6 ± 0·4	36·4 ± 0·4	36·1 ± 0·3	35·9 ± 0·6	35·7 ± 0·6	35·8 ± 0·9

±indicates standard deviation values.

TABLE II

Significance of difference. Stomatal index of Mecardonia dianthera *ecotypes*

Leaf	Statistical Values					
	Tip		Middle		Base	
	O.D	2 S.E.D.	O.D.	2 S.E.D.	O.D.	2 S.E.D.
Dorsal Surface	1·1*	0·16	1·4*	0·24	1·3*	0·84
Ventral Surface	6·1**	0·38	6·1**	0·36	6·6**	0·38

O.D.—Observed difference between two means. *Highly Significant value

2 S.E.D.—Value calculated. **Significant

TABLE III

Stomatal Study of M. dianthera *ecotypes. Average mean Values/leaf (sq. mm.)*

Ecotype	Frequency		Total	Index		Total
	Dorsal Surface	Ventral Surface		Dorsal Surface	Ventral	
Repent (Normal)	237·6	173	410·6	37·5	29·3	66·8
Erect	225·0	222	447	36·3	35·6	71·9

In compact repent ecad, a higher stomatal frequency has been found as compared to that of normal repent ecad of *M. dianthera* (Table I). But the differences disappear in cultures. The stomatal frequency per sq. mm and stomatal index on dorsal surfaces of repent ecotype of *M. dianthera* are higher than those of erect ecotype on the same surface (Table I, III). But reverse is true for the ventral surface of the leaves of the two ecotypes. These difference are retained by culture plants also (Table I). It is apparent from the table II that statistically significant differences occur in stomatal indices at tip, middle and base of leaves between erect and repent ecotype of *M. dianthera* (natural populations). In general, the erect ecotype possesses higher stomatal frequency per sq. mm and stomatal index than that of the repent ecotype (Table III).

Discussion

The plant is gregarious in habit and the intraspecific competition is more than interspecific competition (Kaul, 1965). At Varanasi and its outskirts, the plant appears in July when soil moisture and temperature are favourable to annuals in general (Kaul, 1965).

While the erect ecotype remains strictly confined to moist shady habitats, the repent ecotype occurs from moist shady to dry hard soil subjected to trampling (Kaul, 1965). Hence, the repent ecotype possesses wider ecological amplitude than erect ecotype. Also the erect ecotype is a facultative calcicole while the repent ecotype is an obligate calcifuge (Kaul, 1965, 1967*a*). Thus the restricted ecological distribution of erect ecotype is coupled with its indifference to soil calcium.

The seeds of *M. dianthera* germinate within 4–6 days and seedlings produce first flower even when they are only 21–27 days old. The plants continue vegettive and floral growth only upto 45 days or so. Thus, *M. dianthera* completes its life cycle in a very short span of time in comparison to other annuals especially its associates (Kaul, 1965). In fact it appears, flowers, fruits and seeds under a most favourable period of temperature and soil moisture *i.e.* during the post monsoon period at Varanasi.

Neither the plant nor its mobile propagules, the seeds, are equipped with any special dispersal mechanism. Also at no time, birds or other animals were observed feeding on the seeds. However, seeds being minute and light are blown away by wind resulting in their dissemination and occupation of various habitats. Ridley (1930) regards wind dispersal of small seeds as more efficient than those of large seeds because interspecific competition is much reduced correspondingly. Since the seeds float in water, then germinate successfully in it and also the occurrence of the plant along the margins of pools and puddles etc., water seems an important factor in its dispersal.

There is no difference between erect and repent ecotype as far as the size of the guard cells, stomatal pore and stomatal type are concerned. But the difference in stomatal frequency per sq. mm and stomatal index between natural population of erect and repent ecotype of *M. dianthera* are genetical for they are retained in cultures also. The differences in stomatal indices of these two ecotypes have been found to be statistically significant. Both stomatal frequency per sq. mm and stomatal index are higher in erect in comparison to repent ecotype of *M. dianthera*.

Summary

In the present paper, it is shown that the two edaphic ecotypes of *Mecardonia dianthera* exhibit differential ecological distribution and phenology. There is no

difference between erect and repent ecotype as for as the size of the guard cells, stomatal pore and stomatal type are concerned. But the differences in stomatal frequency per sq. mm and stomatal index between natural population of erect and repent ecotype of *M. dianthera* are genetical for they are retained in cultures also. The difference in stomatal indices of these two ecotypes have been found to be statistically significant. Both stomatal frequency per sq. mm and stomatal index are higher in erect in comparison to repent ecotype of *M. dianthera*.

Acknowledgements

I am highly grateful to Prof. R. Misra, Head of the Botany Department, Banaras Hindu University for his valuable guidance. My thanks are due to C.S.I.R. for financial assistance during the tenure of which the work was done.

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Proc. Nat. Acad. Sci., India, 39(B) I & II, 1969

Studies on the metacercaria of fresh water fishes of India VI. On the morphology of metacercaria of *Isoparorchis hypselobagri* (Billet, 1898) with a note on its development

By

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[Received on 3rd September, 1968]

Isoparorchis hypselobagri (**Billet, 1898**) **Odhner, 1927.**

Out of about one hundred and seventy-eight specimens of *Mystus vittatus* (Bloch) examined during the present investigation (1961–65), only six were found infected with metacercariae of a fluke which, on study, revealed to be the metacercariae of *Isoparorchis hypselobagri* (Billet, 1898) Odhner, 1927. The fishes were mostly obtained from the fish market but thirty-seven specimens were collected with the help of fishermen from "Kukrail" and river "Gomati", but none of the latter were found infected with the metacercaria in question. Besides *Mystus vittatus*, other fishes viz., *Puntius ticto* (Hamilton), *Puntius sophore* (Hamilton), *Labeo calbasu* (Hamilton), *Rita rita* (Hamilton), *Xenentodon cancila* (Hamilton) and *Oxygaster bacaila* (Hamilton) were also examined for the metacercaria and one specimen of *Oxygaster bacaila* (Hamilton) obtained from the fish market on 9th June, 1964 was found infected with a single specimen.

The occurrence of the metacercariae of *Isoparorchis hypselobagri* has been recorded in India by Southwell and Prashad (1918), Bhalerao (1926, 1936), Chauhan (1947), Jaiswal (1957), Bhardwaj (1961), and Rai and Parde (1965) from various fresh water fishes viz., *Barbus tor*, *Ophiocephalus striatus*, *Notopterus notopterus*, *Ophiocephalus marulius*, *Ophiocephalus punctatus*, *Ophiocephalus gachua*, *Mastacembalus armatus*, *Ambasis nana*, *Wallagonia attu*, *Gobius giuris*, *Clarias batrachus*, *Callichrous bimmaculatus*, *Belone cancila*, *Mystus seenghala*, *Mystus vittatus* and *Eutropiichthys vacha*.

The adult fluke, *I. hypselobagri*, is a common parasite of *Wallago attu* which, being a predator, preys upon small varieties of fishes, the latter, when infected, possibly serve as transport hosts. Bhalerao (1932) reported immature forms of *Isoparorchis* sp. from a crocodile and Simha (1958) from a turtle in India. These reptilies do not appear to be the natural definitive hosts, most probably they contracted the infection accidentally by preying upon fishes infested with the metacercariae of *Isoparorchis* sp. Regarding the records of the occurrence of the metacercariae of *I. hypselobagri* from foreign lands, Yamaguti (1934) reported his finding of the metacercariae of this fluke from several fishes in Japan. The present find of the occurrence of the metacercariae of *I. hypselobagri* on *Oxygaster bacaila* adds one more fish to the list of hosts recorded from India.

As the previous authors merely recorded the presence of the metacercariae of *Isoparorchis hypselobagri* in various fresh-water fishes in India without giving any account even of the gross morphology, the writer takes this opportunity to give a

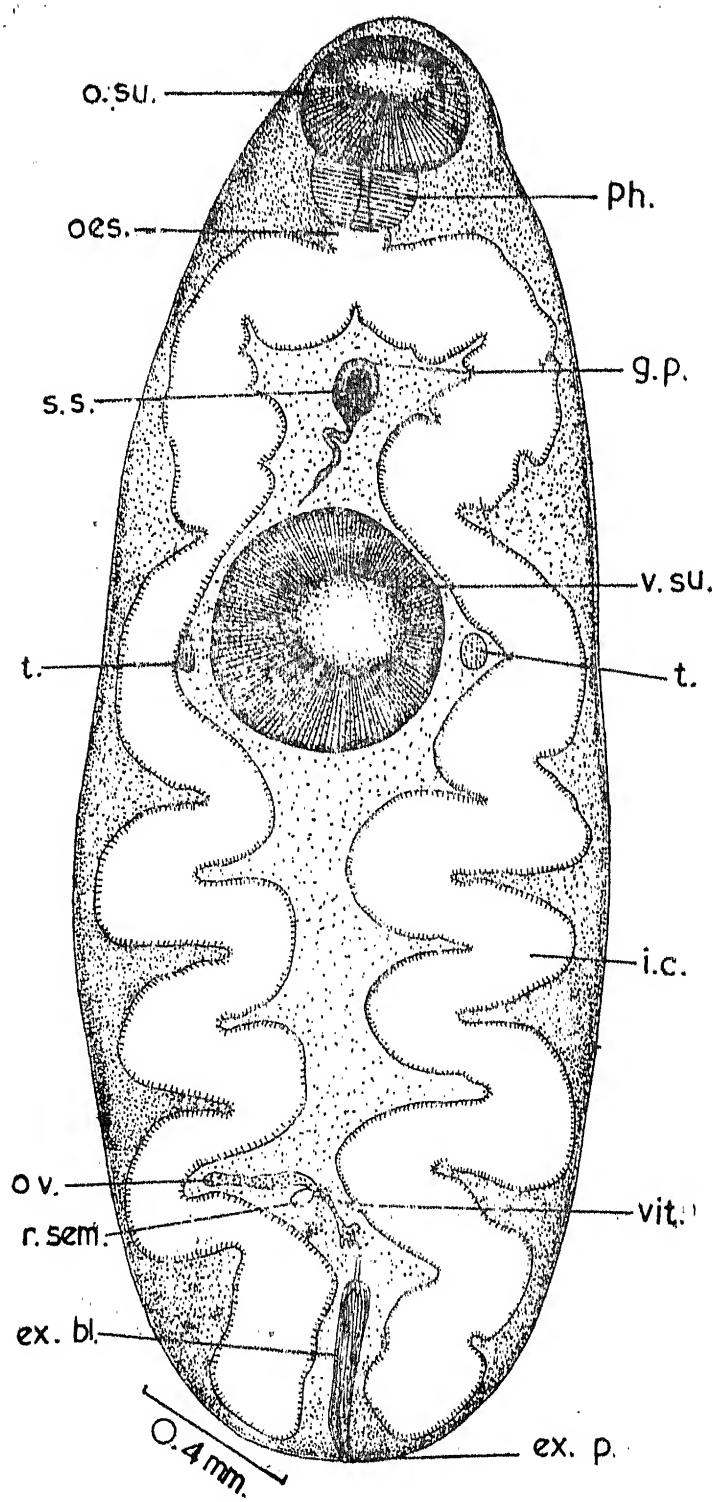

Fig. 1. *Isoparorchis hypselobagri* (Billet, 1898). Ventral view of metacercaria (drawn from a mounted specimen).

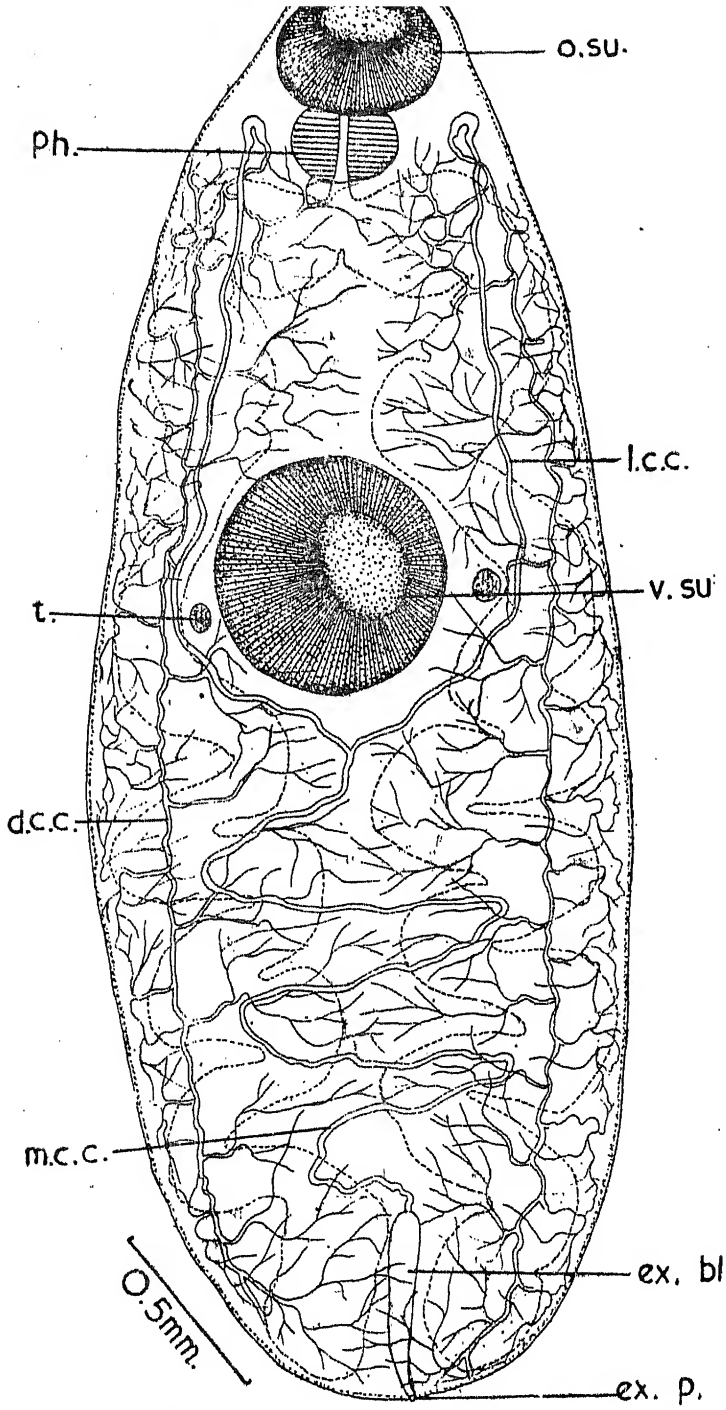

Fig. 2. *Isoparorchis hypselobagri* (Billet). Ventral view of a metacercaria showing the excretory system (drawn from a live specimen).

ABBREVIATIONS USED

d.c.c., descending collecting canal; ex.bl., excretory bladder; ex.p., excretory pore; g.p., genital pore; i.c., intestinal caeca; l.c.c., lateral collecting canal; m.c.c., main collecting canal; o.su., oral sucker; oes., oesophagus; ov., ovary; ph., pharynx; r.sem., receptaculum seminis; s.s., sinus sac., t., testis; v.sem., vesicula seminalis; v.su., ventral sucker; vit., vitellaria.

brief description of the metacercaria, including a criticul account of its excretory system which the writer has been able to work out in fairly good details.

Habitat : The metacercariae, varying from the one to five in number, were obtained from the body cavities of the hosts. They were found not encysted on visceral organs but in free state, and they appeared golden yellow or brown in colour. When taken out in saline from the body cavities of its hosts, it showed active movements of expansions and contractions of its body. The preacetabular portion of body was extremely mobile.

Morphology : Body (Fig. 1) aspinose, thick and elongated, anterior end being more attenuated than posterior end. It measures 1·63 – 3·80 mm. in length and 0·37 – 1·42 mm. in maximum breadth at the equatorial region. Suckers well developed and circular in outline. Oral sucker subterminal and measures 0·09 – 0·36 mm. × 0·12 – 0·31 mm. Ventral sucker much larger than oral sucker, pre-equatorial, situated at a distance of 0·21 – 1·24 mm. from the anterior end of body and measures 0·15 – 0·60 mm. × 0·16 – 0·63 mm. A prepharynx is absent. Pharynx well developed and measurses 0·04 – 0·15 mm. × 0·05 – 0·28 mm. Oesophagus extremely short but easily seen in live specimens. It measures 0·03 – 0·15 mm. in length. Intestial caeca broad and appear yellow or brown with the contained food matters. They run in a sinuous course upto posterior end of body. In the living condition, intestial caeca have been observed undergoing, at random, contractions and thereby ejecting the contents through mouth.

Gonads (Fig. 1), as yet, poorly developed. Testes appear as two small oval or round bodies located at the sides of ventral sucker in the intercaecal field. Right testis measures 0·01 – 0·07 mm. × 0·01 – 0·09 mm. Left testis slightly larger than right testis and measures 0·01 – 0·10 mm. × 0·01 – 0·07 mm. Vasa efferentia arising from testes run forward and eventually unite, in front of ventral sucker, to form a short vas deference which is continued into a narrow vesicula seminalis lying free in the body parenchyma. Vesicula seminalis is continued into a short ejaculatory duct enclosed in the so-called "sinus sac" of Manter (1936). Genital pore median and located behind the intestinal bifurcation.

Ovary is present on the right side in the form of a transversely elongated structure in the hind region of body in front of the excretory bladder. A small pear-shaped receptaculum seminis is present. A Laurer's canal is present. Vitellaria are in the incipient stage of development and are represented by dark staining cells in front of the excretory bladder.

Southwell (1913) described the excretory vesicle as club-shaped. His account, however, lacks details of the excretory system. Chauhan (1953), while giving the generic di agnosis of *Isoparorchis*, mentioned the excretory bladder to be Y-shaped. Yamaguti (1958) in the treatise "Systema helminthum" appears to have followed Chauhan (1953) while giving the diagnostic feature of the genus *Isoparorchis* as he, too, states "excretory bladder Y-shaped". The writer finds the excretory bladder to be a cylindrical structure in this fluke. The club-shaped excretory bladder described by Southwell (1913) is attributable, in the opinion of the writer, to the contraction of the body which usually happens during fixation. The details of the excretory system, as far as the writer could observe in his specimen, are described below :

Excretory bladder (Fig. 2) is an elongated, intercalated between terminal parts of the intestinal caeca, and leads to the outside by a terminal excretory pore. The main collecting canal is formed, near about the middle region of body, by the union of two lateral collecting canals and, thereafter, it runs posteriorly

forming four transverse loops and eventually opens into the excretory bladder. The lateral collecting canals run forward as far as the pharynx wherefrom they turn backwards as the descending limbs of the lateral collecting canals and extend upto the posterior end of body. They give off off-shoots which repeatedly branch and rebranch.

Feeding experiments

To trace the adult from the metacercaria, the following feeding experiments were performed, using specimens of two varieties of fishes viz., *Rita rita* (Hamilton) and *Wallago attu* (Bloch) for feeding purpose. The fishes used for experimental purpose were reared in aquaria in the laboratory and in small tanks of the department from fry obtained from local fishermen. Some small medium size fishes were also obtained from fishermen and maintained in tanks for several months. Before performing feeding experiments, fishes were kept for atleast 6-8 hours in petri dishes containing some water, and faecal matter discharged were collected and examined for helminth ova. This procedure was repeated for about a fortnight and only a few were found infected and these were discarded, others were used in feeding experiments.

Experiment No. 1 : On 20th February, 1963, one metacercaria obtained from the body cavity of a *Mystus vittatus* was fed to one specimen of *Rita rita.* The fish host naturally died on 22nd February, 1963, *i.e* , two days after it was fed. Autopsy of the host was made but no developing metacercaria could be obtained. The metacercaria failed to develop in *Rita rita.*

Experiment No. 2 : On 24th September, 1963, two metacercariae obtained from the body cavity of *Mystus vittatus* were fed to one specimen of *Rita rita.* The fish (*Rita rita*) naturally died on 30th September, 1963, *i.e,* six days after the feeding experiment. At autopsy, no fluke could be obtained. The metacercariae again failed to develop in *Rita rita.*

Experiment No. 3 : On 24th September, 1963, a metacercaria obtained from the body cavity of a *Mystus vittatus* was fed to a specimen of *Wallago attu.* The fish died on 30th October, 1963. thirty-six days after it was fed with the metacercaria. At autopsy, a single worm was collected from the gas bladder of the fish (*Wallago attu*). This was mature worm with eggs in the uterus.

Changes undergone by metacercaria within the exprimental host

The following changes took place in the worm while within the experimental host : body size increases ; gonads fully develop ; vitellaria become prominent and the uterus contains eggs.

Examination of *Wallago attu* for natural infection

The writer examined a dozen large size speciment of *Wallago attu* obtained from the fish market for the infection of *Isoparorchis* and found as many as seven specimens infected. Worms varying from one to four were collected from the gas bladder of these infected specimens of *Wallago attu.* The writer also examined one dozen specimens of *Rita rita,* six of them were collected from the river Gomati and six were purchased from fish market. Unfortunately none of these specimens of *Rita rita* was found infected.

Morphology : The adult form obtained experimentally by the writer from *Wallago attu* is exactly identical with those collected from naturally infected *Wallago attu,* differing only in being smaller in size. As the adult form, *Isoparorchis hypselobagri,* is well described by various workers and the writer finds nothing to

add to the account of the morphology of the adult, a description is deemed unnecessary.

Acknowledgements

The writer is thankful to Dr. S. C. Baugh for the help and guidance and to Professor M. B. Lal, F. N. I. formerly Head, Zoology Department, now Vice-Chancellor, Lucknow University, Lucknow, for Laboratory facilities. Thanks are also due to Government of India for awarding a Research Training Scholarship to the writer.

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Studies on monogenetic trematodes of India I. On a new species of the genus *Eupolystoma* Kaw, 1950 from *Bufo* sp.

By

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[Received on 28th September, 1968]

Two specimens of a monogenetic trematode were collected (on 12th November, 1962) from the urinary bladder of a *Bufo* sp. Sixteen host specimens, collected from the village Gazipur (about four miles from Lucknow City), were examined but only one was found infected. The specimens on study were found to represent a new species of the genus *Eupolystoma* Kaw, 1950 and is described below as *Eupolystoma chauhani** n.sp.

Eupolystoma chauhani n.sp.

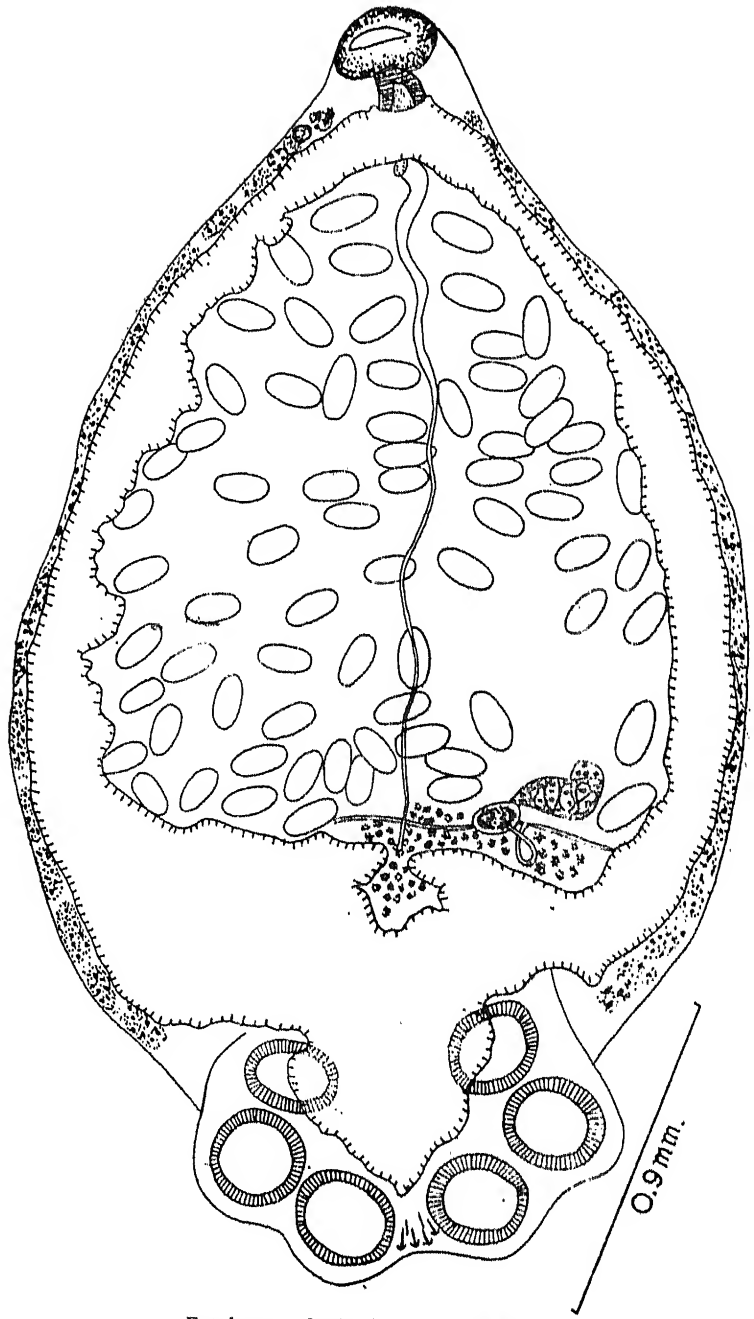
Body aspinose, spindle shaped (Fig. 1), with pointed ends : the anterior end being more sharply pointed than posterior end. It measures 3·24–4·25 mm. in length and 1·20–1·75 mm. in maximum width at middle region of the body. Oral sucker terminal and measures 0·21–0·30 mm. in diameter. Opisthaptor disc-like and measures 1·21–1·35 mm. × 1·32 1·45 mm. and set with three pairs of well developed cup-shaped suckers. Suckers are more or less circular and equal in size and measure 0·12–0·15 mm. in diameter. Six larval hooks, T-shaped with a long blade, are present at the hind border of the opisthaptor in between the last pair of suckers.

Mouth directly leads into a well developed muscular pharynx measuring 0·08–0·09 mm. × 0·06–0·07 mm. A prepharynx and an oesophagus are absent. Intestinal caeca lacks diverticulum ; caecal union located at anterior border of opisthaptor, and a median branch from the caecal union extends posteriorly into the opisthaptor upto the last pair of suckers.

Testes post ovarian and follicular, the follicles being numerous and located just infront of the caecal union and restricted to the left half of the body. Vas deferens long and leads into a wider seminal vesicle. Cirrus coronet with six minute hooks. Genital pore median and located just posterior to intestinal bifurcation.

Ovary club-shaped, lateral in position and located anterior to caecal union. Ootype close to the ovary ; uterine coils occupying all the available inter caecal space and opens at genital pore. Vitellaria, follicular, extend laterally along intestinal caeca from pharyngeal level to posterior end of body. Median vitelline duct, formed by union of two transverse vitelline ducts, opens at ootype. Eggs large, thin shelled and numerous. Some are embryonated while others have well developed larva. Embrynoated egg measures 0·07–0·08 mm. × 0·02–0·03 mm. while larval body measures 0·07–0·09 mm × 0·03–·04 mm.

*The species has been named in the honour of Dr. B. S. Chauhan, Deputy-Director, Zoological Survey of India, Calcutta.



Eupolystoma chauhani n.sp. ventral view.

Host : *Bufo* sp.
Location : Urinary bladder
Locality : Lucknow

Discussion

Euzet and Combes (1967) in their recent paper, have recognized only the two species *viz. E. rajai* Kaw, 1950 and *E. alluaudi* (Beuchamp, 1913) under the genus *Eupolystoma* Kaw, 1950. *E. chauhani* n.sp. chiefly differs from both these species in the position of vitellaria and in the number of larval hooks. Therefore, the writer regards it as a new species. Kaw (1950) placed the genus *Eupolystoma* under the subfamily *Polystominae* Gamble, 1896, which was subsequently followed by Chauhan (1953). Yumaguti (1963) created a new subfamily *Eupolystomatinae* for reception of the genus *Eupolystoma* Kaw, 1950 and is followed here.

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I am thankful to Dr. S. C. Baugh, for his kind help and to Prof. P. D. Gupta, Head, Zoology Department, University of Lucknow, Lucknow for all the laboratory facitilies.

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Observations on the Life History and Bionomics of *Psalis pennatula* F. (Lymantriidae, Lepidoptera), a pest of Sugarcane in Rajasthan (India)

By

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Psalis pennatula F., a polyphagous pest, has been reported to cause widespread damages to sugarcane crop in Burma, Formosa, Indochina and India, (Box, 1953). Butani (1961) also included this pest in the annotated list of insects affecting sugarcane in India. In Rajasthan, which is one of the biggest States of this country, ravages of this pest were observed in August, 1966 during a routine survey of the sugarcane growing areas of this State.

Surprisingly enough, a review of the available literature on this pest revealed that so far nothing is known regarding its life and activities as a pest. Hence an attempt has been made in this paper to present the details of its life-history and bionomics for the first time.

Material and Methods

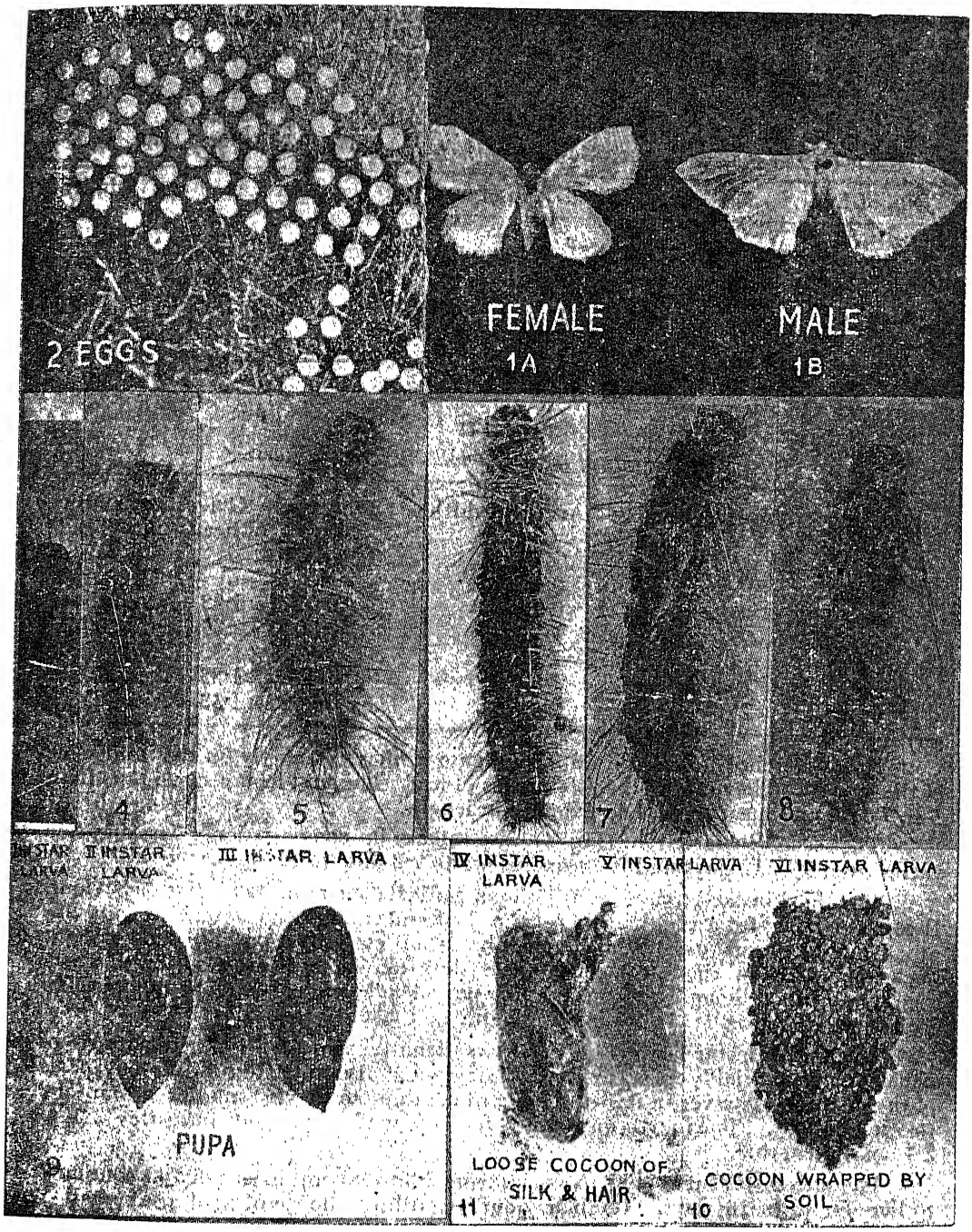
A large number of caterpillars and egg masses were collected from sugarcane fields of different parts of Rajasthan. The eggs were kept over moist blotting paper in petridishes (10 cm. diameter). Fresh and tender leaves of sugarcane were provided adlibitum to the larvae. Food was changed twice in 24 hours. The last instar larvae were transferred to glass jars containing soil collected from the sugarcane fields to facilitate pupation. On emergence the adults were released in cages $1' \times 1' \times 1'$. Fresh leaves and pieces of blotting paper were kept in the cages for egg laying. Adults were provided 10% glucose solution as food. Rearing was done at Udaipur under laboratory conditions, from August to October, 1966 and from June to October in 1967.

Viability of Eggs

Eggs are laid in clusters on both the surfaces of the leaf, is round and shining white in colour. It's diameter varies from ·3 to ·6 mm. Incubation period is from 5 to 8 days. An experiment was conducted to determine the viability of eggs in the month of July, 1967. The data obtained are presented in table I.

Larvae

There are six larval instars. The colour variations in different instars have been presented in table III. To ascertain the number of instars the head width of different larval instars were also taken besides observing their exuvial. It will be seen from table II that there was almost a constant difference of about 0·3251 mm. between the head widths of successive instars. Thus the average ratio


2 EGGS
FEMALE
1A
MALE
1B
4
5
6
7
8
I INSTAR LARVA
II INSTAR LARVA
III INSTAR LARVA
IV INSTAR LARVA
V INSTAR LARVA
VI INSTAR LARVA
PUPA
9
LOOSE COCOON OF SILK & HAIR
11
COCOON WRAPPED BY SOIL
10

of increase in successive instars was 1·33 : 1 approximately. The measurements of observed and calculated head widths of different instars are so close that there appears hardly any possibility of any instar having been overlooked. Moreover the data given in the table show a regular progression in head widths in accordance with Dyar's law.

TABLE 1

Viability of eggs of P. pennatulas *under laboratory conditions in July*, 1967

No. of Expt.	No. of eggs tested	No of eggs hatched	Percent of egg viability
1	48	43	89·5
2	71	67	93·4
3	38	36	94·7
4	29	27	93·1
5	56	53	94·6
		Average	93·06

TABLE II

Measurements of the head widths in larval instars

Instar	No. of larvae	Average width	Observed=Calculated width of head (mm.)
1	15	0·4725	–
2	15	0·8050	0·0725 × 1·33=0·617325
3	15	1·1375	0·8050 × 1·33=1·070650
4	15	1·4700	1·1375 × 1·33=1·509575
5	15	1·8025	1·4700 × 1·33=1·955100
6	15	2·0975	1·8025 × 1·33=2·397325

Newly hatched larvae (Fig. 3) congregate in masses, mostly on the underside of the leaves. They nibble the soft tissues of leaf. The first instar larvc lasts from 5 to 7 days and measures 3·4 to 4·8 mm. in length.

The second instar larvae (Fig. 4) also remain in congregation. Its duration varies from 9 to 12 days and it measures 6·5 to 7·8 mm. in length.

The third instar larva (Fig. 5) shows a radical change in its feeding behaviour. It starts feeding from the margin of the leaf and makes charactertisic cuts like other lepidopterous caterpillars. The habit of congregation also shows slight slackening since in the latter part of the duration of this instar a few of them migrate and start living for a considerable period independently of the main group. This larva measures 1·3 to 1·5 cm. in length and lasts 10 to 15 days.

The fourth instar larva (Fig. 6) shows definite signs of isolated pattern of behaviour. Invariably these larvae feed singly and also migrate to different parts of the plants. However, a few of them still continue to live in smaller groups of 2 to 4 individuals. The fourth instar lives for 11 to 17 days and measures 2·0 to 2·4 cm. in length.

The fifth instar larva (Fig. 7) varies from 2·8 to 3·5 cm. in length and continues to live for 10 to 16 days. Its behaviour regarding the habits of congregation conforms to that of fourth instar larva.

TABLE III

Colour pattern of larvae during different instars of P. pennatula

Colour of	Instars					
	1	2	3	4	5	6
Head	Light brown	Brown	Deep brown	as in 3rd	as in 3rd	as in 3rd
Frons	White	Yellow white	Yellow white	Yellow white ; 2 long white patches present on either side of epicranial suture.	Yellow white ; with light brown patches present on either side of epicranial suture.	as in 5th
Ocelli	Deep brown	Deep brown with a row of 4 to 5 dorsal white patches	as in 2	Glassynin appearance	as in 4th	as in 4th
Clypeus	Yellow white	Yellow white	Yellow white	Yellow white	Light brown	Brown
Antenna	Yellow white	Yellow white	Yellow white	Yellow white	Light brown	Brown
Mandible	Light brown	Deep brown basal segment yellow white	as in 2	as in 2	Deep brown black lateraly	as in 5th
Thorax						
Prothoracic Shield	Cream colour	Yellow white	Light brown	Deep brown	as in 4th	as in 4th
Thoracic legs	Dirty white	Yellow white	Light brown	as in 3rd	as in 3rd	as in 3rd
Sternum	Egg white	Light brown	Light brown	Light brown with black dots.	as in 4th	as in 4th
Spiracle	Light brown with a deep brown peritreme	as in 1st	as in 1st	Light brown with dark brown peritreme.	Light brown with black peritreme.	as in 5th

Colour of	Instars					
	1	2	3	4	5	6
Abdomen						
Pro-leg	Dirty white	Dirty white, distally light brown	Light brown, distally black	as in 3rd	Brown, distally black	as in 5th
Spiracle	Dirty white with light brown peritreme.	Dirty white with deep brown peritreme.	as in 2nd	as in 2nd	Diry white with peritreme	as in 5th
Anal segment	Light Yellow	Light brown	Dark brown	as in 3rd	Black	as in 3rd
Sternum	Egg white	as in 1st	Light brown	Light brown with dark brown patches.	as in 4th	as in 4th
General body colour	Light yellow	as in 1st	Light brown	as in 3rd	Deep brown	as in 5th
Spots	24 Light brown spots arranged in two parallel rows.	as in 1st	as in 1st	as in 1st	Light brown pigmentation appears between the spots and thus two brown parallel lines are formed from Meso-thoracic segment to the anal segment.	as in 5th
Body hairs	Dirty white in colour	as in 1st	as in 1st	Dirty white and light brown	Groups of dirty white light brown and dark brown hair.	as in 5th

The last *i.e.* the sixth instar larva, (Fig. 8) which measures 3·9 to 4·4 cms. lives for 9 to 21 days, feeds voraciously upto a period of about one week. After that it starts losing its appetite. It does not live in congregation.

Larval Mortality

To assess the larval mortality in successive instars direct observation were taken. Percent cumulative mortality in different instars were calculated (Table IV). Maximum mortality was observed, when the 5th instar larvae change to sixth instar. Besides other reasons which are yet to be investigated a dipterous parasite *Paleroxista solennis* Wlk. of family Tachinidae has been found to cause mortality among full grown larvae. A brief estimate made on the basis of field collections showed the occurrence of this parasite in 5% population.

TABLE IV

Larval mortality in different instars

No. of Expt.	No. of 1st instar larvae	Percent cumulative mortality in different instars				
		2nd	3rd	4th	5th	6th
1	135	2·9	8·8	10·4	11·4	20·7
2	121	3·3	6·6	8·3	10·0	17·9
3	97	2·1	8·2	10·3	11·1	19·4
4	104	2·8	9·5	10·5	13·3	14·2
5	52	1·9	7·8	9·8	13·7	23·5
6	113	2·3	5·3	5·9	9·8	16·6
Average		2·6	7·7	9·2	11·6	22·05

Pupation

The mature larva descends down from the plant and reaches the ground. Further events now depend on the degree of compactness of the soil. In case of loose soils the larva bores into the ground and makes the puparium into the tunnel. A loose cocoon of silk and hair is formed which is further wrapped up by soil particles (Fig. 10). Such pupae have been recovered upto a depth of about 9 cm.

When the soil is compact, dry and hard the larva fails to make a tunnel and as such pupates on the surface itself. In such cases, pupation takes place between dead and dry leaves. The latter are glued together to from an outer cover of the puparium.

Pupa

The pupa (Fig. 9) is obtect and dark brown in colour. It measures 1·3 to 1·8 cm. in length and 4 to 6 mm. in breadth across the wing pads. It lives normally from 6 to 8 days. Its body remains enclosed in a closely fitting sheath. The antennae, wings and legs lie against the lateral and ventral surfaces. The two eyes are prominently marked out. Abdomen is covered with a thin sheath. The anal segment bears a pointed cremaster. The abdomen of male pupae are relatively narrower and darker in colour than those of females.

The larvae which pupate in late September and Octorber undergo hibernation till next year upto June and July. Under the latter condition the time spent in pupa extends up to nine months.

Emergence of adults

Emergence of moths takes place after the early shower of rains in June or July. The pupa remains quiescent until a few days before the moth is ready to emerge. A longitudinal split from the anterior end down to the thorax takes place. The head comes out first and then follows the thorax and abdomen. The moth reaches the open surface by wriggling movements removing the adjacent soil which gets softend due to rains. The wings then spread and the moth frees itself from the soil particles attached to its body. Within a short duration it takes up its first flight.

The adult of *P. pennatula* is dirty yellow in colour. Females (Fig. 1) are stouter than males (Fig. 2). The moths are rarely seen during the day. They are phototropic, a good many of them have been caught from the light traps. In the laboratory they survived from 3 to 5 days. Though a number of male and female adults were released in the cage and were kept under constant observation yet their courtship and copulation could not be observed.

Nature and extent of damage

Attack of this pest is exclusively confined to the leaves as far as sugarcane is concerned. A monthly estimates of its population has been made at the farm of Sahalion-Ki-Bari, Udaipur. The average population of the caterpillars remains approximately 10,000/hec. in August. Its population declines to 5,000/hec. during the last week of September. A further fall in population to 1,000/hec. is noticed in October. It has been observed that some fields are, infested so severely that few plants of sugarcane are denuded completely of their leaves.

Seasonal History and distribution

The pest appears in June/July just after the early rains. Egg masses are found in large number in the field upto August. The population of the pest is reduced considerably by the end of October and they disappear almost completely from the fields by the end of November.

The pest has been found to be serious so far at Bhupalsagar, Chittorgarh, Kota and Sriganganagar. Its population at Udaipur, Bhilwara and Dungarpur also remains moderately high.

Summary

P. pennatula F. is a pest of sugarcane in Rajasthan. Its biology, nature and extent of damage, seasonal history and distribution have been studied for the first time.

The female moths lay eggs in clusters both on the upper and lower surfaces of the leaf. There are six larval instars. Pupation takes place in soil. The life cycle is completed within 65 to 104 days.

Acknowledgements

The authors are thankful to Dr. B. K. Srivastava, Director of Research, for providing laboratory facilities. We are also thankful to the authorities of Commonwealth Institute of Entomology, London for identifying the pest and its parasite.

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The Jaw Muscles of Some Indian Birds

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The feeding behaviour of birds has always been a fascinating subject and a good deal of work has been done to study this aspect of bird life. However, a study of correlation between the feeding behaviour and structural adaptations in the anatomy of the feeding apparatus has not attracted the attention it deserves. Beecher (1951 and 1953) was among the first investigators in this field and worked on jaw muscles of Passerines in relation to their feeding habits. Of particular interest is the work of Goodman and Fisher (1962) who have worked on the functional anatomy of the feeding apparatus in waterfowls. The work of Zusi (1962) also throws considerable light on the functional anatomy of the jaw muscles of Black skimmer (*Rhynchops nigra*) and allied birds. Very recently Rawal (1966) and Malhotra (1967), have worked on the functional anatomy of feeding apparatus of certain picarian group of birds and passerines respectively.

The accompanying description of the jaw muscles in different birds is mainly based on the observations made in our laboratories and is intended to note variations which exist in their gross anatomy. The birds selected for studies include :

I. Picarian and allied group of birds

1. Blue rock pigeon
   (Columba livia intermedia STRICKLAND)
2. Koel
   (Eudynamys scolopacea scolopacea LINNAEUS)
3. Rose-ringed parakeet
   (Pstittacula krameri borealis NEUMANN)
4. House swift
   (Apus affinis affinis J. E. GRAY)
5. Green Bee-eater
   (Merops orientalis orientalis LATHAMUS)
6. Hoopoe
   (Upupa epops epops LINNAEUS)

II. Passerine group of birds

7. House sparrow
   (Passer domesticus LINNAEUS)
8. Jungle babbler
   (Turdoides somervillei SYKES)
9. Drongo
   (Dicrurus macrocerus VIELLOT)

10. Shrike
(Lanius schach LINNAEUS)
11. Red vented bulbul
(Pycnonotus haemarrhus pallidus STUART BAKER)
12. Tree-pie
(Crypsirina vagabanda LATHAM)
13. House crow
(Corvus splendens VIELLOT)

III. Egrets and herons (Unpublished work, Mansuri)

Functionally the jaw muscles of birds may be divided as adductors and abductors of the lower jaw and protractors and retractors of the upper jaw. Nevertheless it may be noted that the working of a muscle is not necessarily limited to one function. For instance it is observed that all the retractors of the upper jaw also function as adductors and the former function is well marked in those birds which are well known for a higher degree of kinesis of the upper jaw.

Based on their main functions, the jaw muscles of the feeding apparatus of birds may be grouped as follows :

I. Adductors of the lower jaw
1. Adductor mandibulae externus
2. Adductor mandibulae medius

II. Adductors of the lower jaw and retractors of the upper jaw
3. Adductor mandibulae internus
4. Pseudotemporalis profundus
5. Adductor mandibulae posterior

III. Abductors of the lower jaw
6. Depressor mandibulae

IV. Protractors of the upper jaw
7. Sphenopterygoquadratus

It is observed that in most of the birds these muscles are further divided and subdivided.

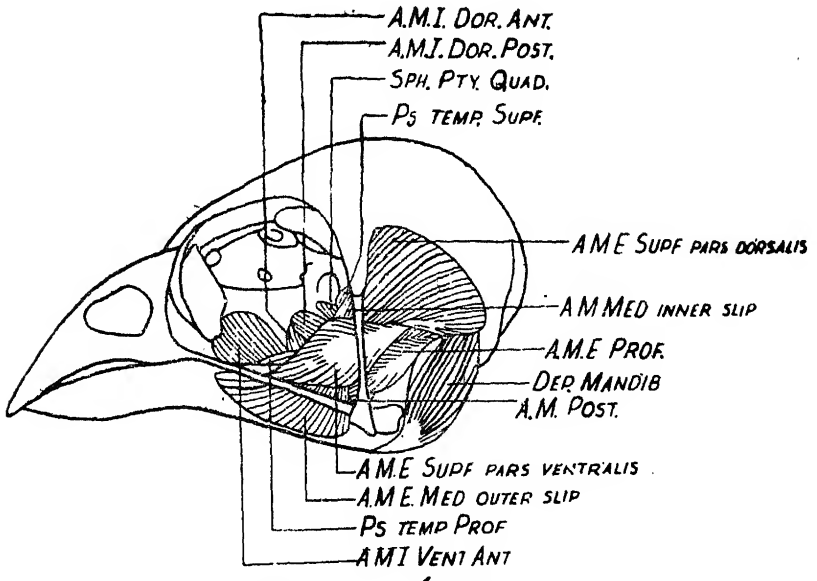
In naming the jaw muscles, the terminology of Edgeworth (1935) has been adopted here as it is based mainly on the development of the muscles and their innervation. It may be mentioned here that the terminology adopted by different authors is not uniform. For instance, Edgeworth (1935) describes the three parts of Adductor mandibulae as M. A. M. externus, M. A. M. medius and M. A. M. internus. The term A. M. externus is retained as such by all authors. But A. M. medius is termed by Lakjer (1926) as Pseudotemporalis and Adductor mandibulae posterior and A. M. internus as Pterygoideus (dorsalis and ventralis). On the other hand, Beecher (1951 and 1959), Goodman and Fisher (1962) and Zusi (1962) describe the A. M. medius as Pseudotemporalis Superficials. Further these authors also describe the Pseudotemporalis muscle as Pseudotemporalis profundus.

The Sphenopterygoquadratus has been termed as Protractor quadratus by Beecher (1951, 1953), Goodman and Fisher (1962) and Zusi (1962) based on its function as a protractor of the uper jaw.

EXPLANATIONS OF DIAGRAMS AND ABBREVIATIONS

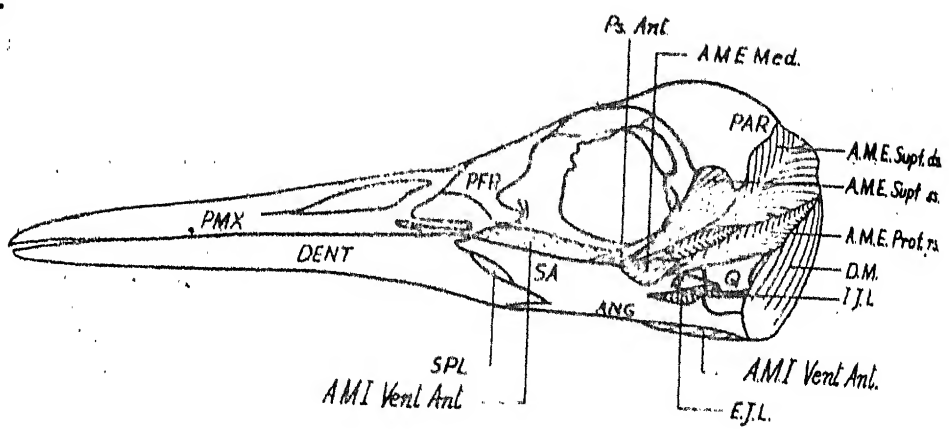
Fig. 1, 2 & 3 : Superficially observed jaw muscles of the 1. House sparrow, 2. Cattle egret and 3. House crow respectivety.

A.M.E. Med. Inner slip—Adductor mandibulae externus medialis inner slip ; A.M.E.Med. Outer slip.—Adductor mandibulae externus medialis outer slip ; A.M.E. Prof.—Adductor mandibulae externus profundus ; A.M.E.Supf. pars dorsalis—Adductor mandibulae externus superficials pars dorsalis ; A.M.E. Supf. pars ventralis—Adductor mandibulae externus superficialis pars ventralis ; A.M.I. Dors. Ant.—Adductor mandibulae internus dorsalis anterior ; A.M.I. Dors. Post.—Adductor mandibulae internus dorsalis posterior ; A.M.I. Vent. Ant.—Adductor mandibulae internus ventralis anterior ; A .M.I. Vent. Post.—Adductor mandibulae internus ventralis posterior ; A.M. Med.—Adductor mandibulae medius ; A.M. Post.—Adductor mandibulae posterior ; Dent.—Dentary ; Dep. Mandib.—Depressor mandibulae ; Par.—Parietal ; Pfr.—Prefrontal ; PMX—Premaxilla ; Q—Quadrate ; Ps. Ant.—Pseudotemporalis anterior ; Ps. Temp. Prof.—Pseudotemporalis profundus ; Ps. Temp. Supf.—Pseudotemporalis superficialis ; SA—Surangular ; SO—Supraoccipital : SQ—Squamosal ; Sph. Pty. Quad.—Sphenopterygoquadratus ;



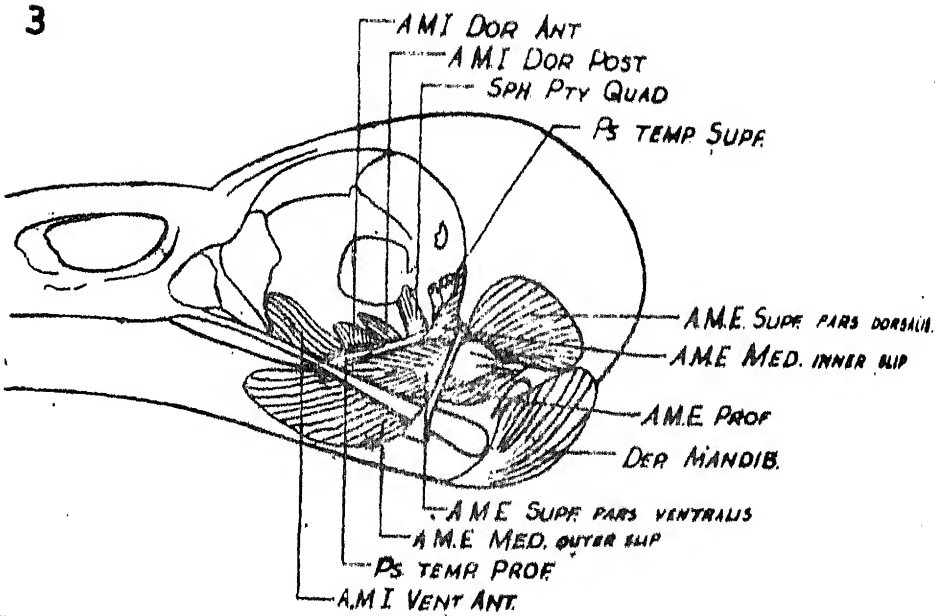
House sparrow (Passer domesticus)

2

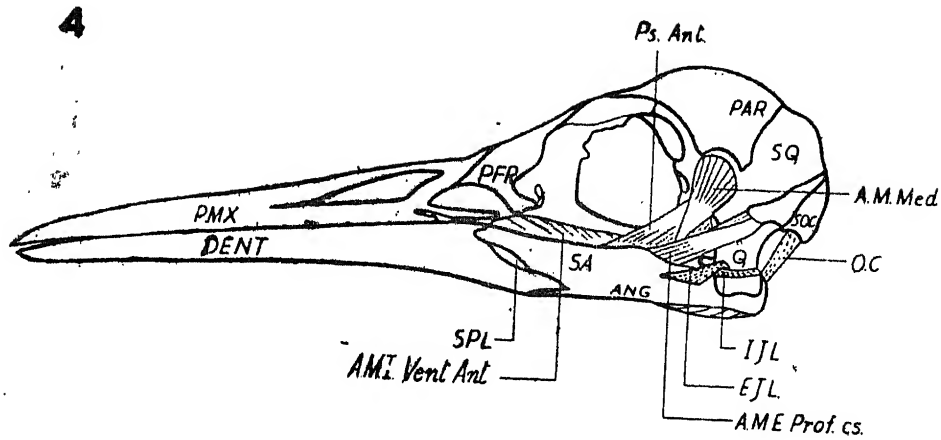


Cattle egret (Bubulcus ibis)

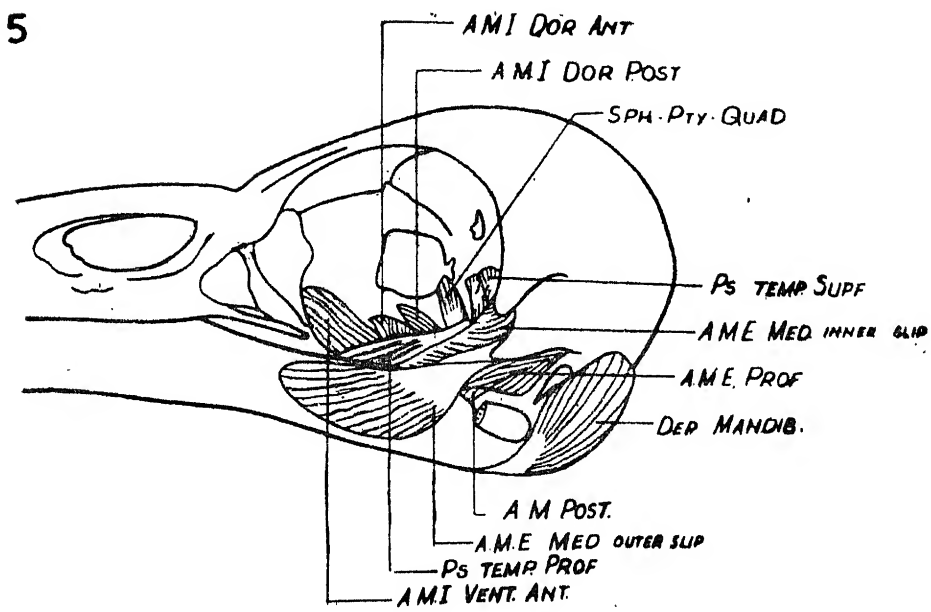
3



House crow (Corvus splendens)



Cattle egret (Bubulcus ibis)



House crow (Corvus splendens)

Fig. 4 & 5 : Jaw muscles (other than superficial series) of the 4, Cattle egret and 5. House crow respectively.

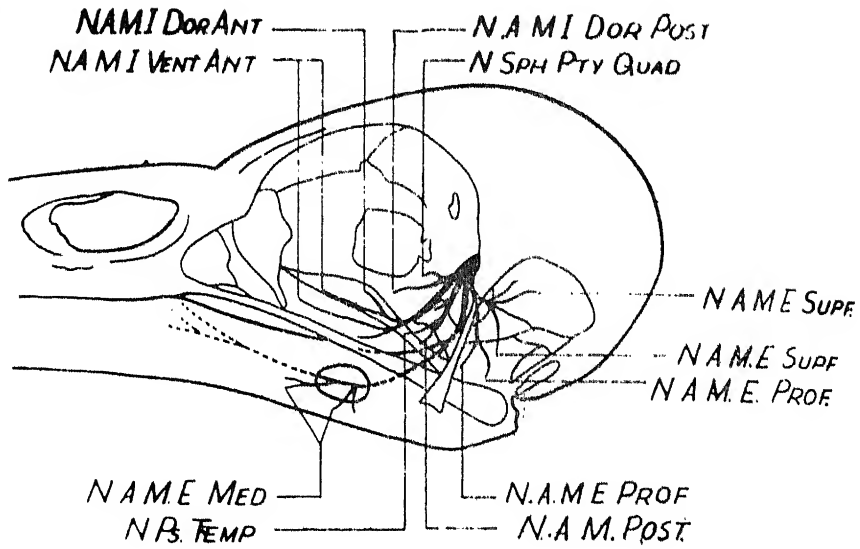


Fig. 6 : Diagram showing the various branches of the V nerve innervating different jaw muscles as observed in the House crow.

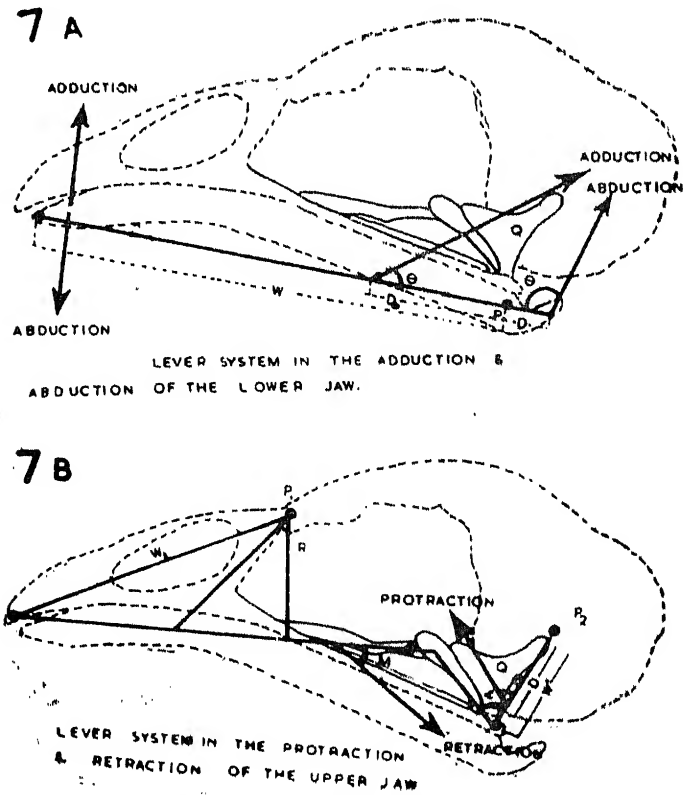


Fig. 7*a* & 7*b* : Schematic diagrams showing the lever system and the force exerted by the operating muscles in a typical bird.

D—Force arm; P, P_1, P_2—Pivot ; Q—Quadrate ; W, W_1—Work arm.

(A) *Adductors of the lower jaw* : (Fig. 1, 2, 3, 4).

1. *M. Adductor mandibulae externus*

The muscles belonging to this series generally serve as powerful adductors of the lower jaw and are further divided into a superficialis, a medialis and a profundus parts.

1*a*. *M. A. M. E. superficialis*

This muscle has been described as a single unit by Davis (1953), Beecher (1951, 1953) etc. In waterfowls, it is divided into three parts (Goodman and Fisher, 1962). In Grus americana (Fisher and Goodman, 1955), certain Indian passerines, herons and egrets this muscle consists of two parts only. Whether it consists as single unit or is divided further, it arises from the temporal region of the skull, moves forwards, downwards and inwards and inserts on the outer surface of the surangular anterior to below and/or behind the coronoid process or on the coronoid process itself. The dorsalis part of this muscle remains mainly fleshy in seed eater (house sparrow), frugivorous birds (rose-ringed parakeet and koel) and insectivorous birds (green bee-eater and jungle babbler), known to feed upon insects while on wings. The arrangement of the muscle fibres may be parallel and/or with well developed pinnate arrangement. But in carnivores such as those feed on carion *e.g.* tree pie and cattle egret which also feeds on ticks and mites, the muscle tends to be more and more tendinous towards the insertion. As for the shrike which is a strong carnivore and feeds on reptiles, small birds and even small mammals, both the dorsal and ventral parts are aponeurotic and the pinnate bundles are large and conspicuous. The same is true of tree pie, which, besides feeding on eggs, is also well known as a flesh eater.

1*b*. *M. A. M. E. medialis*

In a number of birds this muscle develops only as a single unit. But in certain passerines it is divided into an outer and an inner slips. The muscle arises variously from the dorsal border and upper surface of pseudotemporal fossa, postorbital process of the frontal and the zygomatic process of the squamosal. In relation to the origin of the A. M. E. superficialis, this muscle arises anterior to and below that of the former. The muscle fibres usually show bipinnate arrangement. The insertion is broad, generally partly tendinous and partly fleshy. In some forms it is entirely tendinous (as in most of waterfowls). The attachment of the insertion is below and in most forms anterior to that of the A. M. E. superficialis. In house sparrow, crow, shrike and drongo, the muscle is separated into two slips.

1*c*. *M. A. M. E. profundus*

Unlike the other muscles of the A. M. E. series, the profundus part does not exhibit wider variations in different birds. The arrangement of the muscle fibres is generally bipinnate and in some birds including tree pie and cattle egret, it becomes complex and multipinnate as these birds, which are carnivores and insectivores, are often required to exert a great force while collecting the food. It is interesting to note that the multipinnate arrangement is also observed in house sparrow, which is mainly a seed eater.

The origin of this muscle is partly fleshy and partly tendinous from the upper surface of the otic process of the quadrate and/or the adjoining processes of the squamosal generally below the origin of A.M.E. superficialis and behind to that A.M.E. medialis. Usually the muscle inserts by a strong tendon except in

a few birds *e.g.* house sparrow, where the insertion is partly fleshy and partly tendinous towards the condylar surface.

2. *M. Adductor mandibulae medius* (Fig. 4, 5).

This muscle arises from the posterior wall of the orbit and extends to the lower jaw where it inserts on inner surface of the surangular. The origin may be entirely fleshy as in pigeon (Dubale and Rawal, 1962) or partly fleshy and partly tendinous as in shrike and whooping crane (Fisher and Goodman, 1955).

The belly is broad and pinnate in nature and in some birds such as a house sparrow it assumes a complex multipinnate structure. The insertion is strongly tendinous and slightly fleshy as in the house sparrow, drongo and shrike or it may be tendinous alone in jungle babbler and in cattle egret. Still in some others it is entirely fleshy *e.g.* house swift.

(B) *Adductors of the lower jaw and the retractors of the upper jaw* :

While describing these muscles, they are treated here as if they are adductors alone and their origins and insertions have been described accordingly. While considering these muscles as retractors, the origins may be read as insertions and *vice versa*.

3. *M. Adductor mandibulae internus* (Fig. 1, 2, 3, 4).

This is the best developed muscle of the adductor series forming a basal portion of the orbit. The muscle is divided into two main parts *viz.* a ventralis and a dorsalis. The ventralis part occupies an anterior position whereas the dorsalis part is situated behind the former. In most of the birds studied, these portions were further divided into an anterior and a posterior parts.

M. A. M. I. Ventralis, anterior.

This muscle is better developed than its posterior counterpart. It arises variously from the dorsal surface of the posterior half of the palatine bone and moves outwards and backwards. The belly is broad and provided with an aponeurotic sheet towards the insertion, which is broad and partly fleshy and partly tendinous on the anteromedial surface of the articular process and may extend to the articular surface anterior to the former process.

M. A. M. I. Ventralis, posterior.

The muscle arises posterior and internal to the anterior counterpart along the ventral surface of the posterior region of the palatine. The origin may be fleshy alone or partly fleshy and partly tendinous. The muscle fibres show wide variations ranging from single unipinnate to complex multipinnate structure. The insertion is partly fleshy and partly tendinous on the articular process behind that of its anterior counterpart.

M. A. M. I. Dorsalis, anterior.

In a few birds such as a cattle egret this muscle remains as a single unit. But generally, it is divided into an anterior and a posterior parts. Of these the anterior part arises from the posterior region of the latero-dorsal surface of the palatine and/or the dorsal surface of the pterygoid. The muscle is not massive and is mostly fleshy with a slight tendinous region towards the insertion. The insertion is on the articular bone above that of the A. M. I. Ventralis, posterior muscle.

M. A. M. I. Dorsalis, posterior.

The muscle arises in a fleshy or partly fleshy and partly tendinous origin from the dorsal surface of the pterygoid bone. It shows wide variations in development, though in general it is mainly fleshy with its fibres showing unipinnate arrangement. The insertion which is on the basal portion of the articular extends at times on the mandibular foot of the quadrate, is partly fleshy and partly tendinous.

4. *M. Pseudotemporalis profundus* (Fig. 3, 4).

The muscle arises from either side of the orbital process of the quadrate, runs downwards and forwards so as to insert on the fossae of the surangular situated along the posterior region of the inner surface. In well developed muscles the insertions may extend on either side of the fossae. The development of the muscle is well marked in those birds which show a high degree of kinesis of the upper jaw.

It is a unipinnate muscle arising partly fleshily and partly tendinously. The insertion is broad and fleshy.

5. *M. Adductor mandibulae posterior* (Fig. 5).

This muscle has been observed as a single unit except in *M. merganser* and *Ocdemia american* (Goodman and Fisher, 1962) where it divides into two parts, though both of them constitute as a single functional unit. The muscles arises fleshily or partly fleshily and partly tendinously from the dorsal surface of the quadrate extending in some birds as far as its orbital process. The muscle runs downwards and inserts mostly in a fleshy attachment on the depression of the articular immediately behind the anterior condyle.

(C) *Depressors of the lower jaw* (Fig. 1, 2).

6. *M. Depressor mandibulae.*

Only one muscle, M. Depressor mandibulae serves and abductor of the lower jaw. It is a massive muscle occupying lateral caudal region of the skull. The muscle arises mainly from the occipital region below the squamosal bone. In some birds the origin also extends of the latter bone. Most of its fibres run downwards exhibiting a parallel type of arrangement. The posteriormost fibres run downwards and converge forwards towards the insertion, which is on the articular process of the mandible, may be entirely fleshy or partly fleshy and partly aponeurotic. The latter type of insertion is generally observed in the birds with a strong gape. In a few birds including upupa and lanius the muscle is further divided into two slips. Though the main function of this muscle is the depression of the lower jaw, it also serves as a protractor of the upper jaw.

(D) *Protractor of the upper jaw* : (Fig. 5).

7. *M. Sphenopterygoquadratus.*

This muscle is observed to be the deepest of all the muscles situated in the orbit of the eye, below the optic foramen. The muscle arises usually in a fleshy origin from the alisphenoid and may extend above on the orbitosphenoid and below as far as the antero-lateral margin of the basisphenoid. The muscle fibres show unipinnate type of arrangement being provided with a tendinous portion towards the insertion which is partly fleshy and partly tendinous on the quadrate and pterygoid bones.

Innervations : (Fig. 6).

Except Depressor mandibulae, all the muscles are innervated by different branches on the ramus mandibularis of the Vth nerve. The M. depressor mandibulae, on the other hand, is served by a branch of the ramus facialis of the VIIth nerve.

Discussion

It is a common knowledge that the birds exhibit a very wide divergence in their feeding behaviour and fill every food niche available to them. This divergence in the feeding behaviour is reflected mainly by the nature of the varied bills whose prosaic functions lay in handling the food before it is finally gulped down the throat. The house swift (Apus affinis) for instance which scoopes its food into open mouth while on wing, has small bills whereas hoopoe (Upupa epops epops) which feeds mainly by thrusting its bill into the soil has a long bill. The voracious insects eater, drongo (Dicrurus macrocerus), capable of feeding on wings has a strong hooked and slightly elongated bill. For operation of these bills it is essential that the development of the jaw muscles is structurally related to those feeding habits.

Adductors of the jaw : (Fig. 7*a*).

During the process of adduction the quadrato-articular joint serves as a pivot and the muscles arising mainly from the temporal region of the skull pull up the lower jaw. The muscles which serves mainly as adductors arise variously from the lateral regions of the cranium and the pseudotemporal fossa and the inner wall of the orbit. The insertion is on either surface of the surangular. The Adductor mandibulae externus series of muscles which serve as powerful adductors of the lower jaw show wide variations in their development. Birds which feed on small insects tend to have a massive muscle consisting mostly of fleshy fibres as observed in drongo and pycnonotus. In few forms it may show simple pinnate arrangement (Apus affinis). On the other hand the cattle egret, which is required to pull out ticks from the bellies of the cattle and lanius which is required to tear the flesh, the pinnate arrangement of these muscles is well defined and assumes multipinnate structure.

The medialis and profundus parts of the A. M. Externus muscle play a secondary role in the adduction of the jaw and do not exhibit wider variation in the structure and show a bipinnate type of arrangement. The profundus part may however show a complicated multipinate arrangement as in the tree pie, which often uses a great force in tearing the flesh of the prey.

The A. M. Medius is inserted more or less at right angle on the work arm and serves as a powerful adductor muscle. The belly is pinnate in nature and may assume multipinnate arrangement in the house sparrow. The action of such muscle may not be quick but serves to exert a powerful hold of longer duration.

Retractors and Adductors of the jaws : (Fig. 7*a*, 7*b*).

The retraction of the upper jaw is brought about by a backward and downward movement of the palatine, pterygoid and quadrate. This movement is brought about by the contraction of the A. M. Internus series of muscles, the A. M. Posterior and the Pseudotemporalis profundus, all which play a dual role, both as adductors and retractors of the lower and upper jaws respectively. The latter function is more pronounced in the upper jaw with a well developed fronto-nasal hinge which serves as a pivot. The A. M. Internus series brings about the

retraction by pulling the palatine and/or pterygoid backwards. The A. M. Posterior and the Pseudotemporalis profundus also bring about the retraction by applying force on the orbital proces of the quadrate, resulting in a backward movement of the quadrate which now pulls the pterygoid and palatine backwards.

The development of those muscles which bring about retraction shows a wide variation structurally. The muscles are massive but the arrangement of fibres varies from parallel to complicated pinnate pattern. Presumably the total effective force play an important part in retraction. The investigations of Malhotra (1967) reveal that the total effective force of retraction is higher in Crypsirina (0·058039) a flesh tearing bird than in passer (0·011790) which is not required to exert a great force of retraction and whose kinesis of the upper jaw is poorly developed.

Depressor of the jaw : Fig. (*7a*).

The depression is brought about by the downward pushing of the lower jaw by the Depressor mandibulae which is the only abductor muscle of the lower jaw and individual variations are not very conspicuous. The muscle is massive and most of its muscle fibres show mainly a parallel type of arrangement and have aponeurotic areas in the posterior region. Such a structure is indicative of the fact that often the birds are called upon to open the mouth suddenly and quickly.

Protractor of the jaw : (Fig. *7b*).

The protraction of the upper jaw is brought about by the forward movement of the quadrate, pterygoid and palatine. This is made possible by the contraction of the Sphenopterygoquadratus muscle which pushes the quadrate and the pterygoid forwards. The palatine which is connected with these bones pushes the maxilla upwards producing an upward movement on the fronto-nasal hinge. Structurally the protractor muscle *viz.* Sphenopterygoquadratus does not show a wide variation in different birds. But it appears that the total effective force of this muscle is higher in flesh eaters *e.g.* tree pie, shrike and crow than in mere seed and insect eaters *e.g.* house sparrow and drongo.

Summary

1. The jaw muscles of the feeding apparatus of birds have been described with reference to some picarian group of birds, passerines and herons.

2. Functionally they can be divided into the following groups (1) Adductor of the lower jaw (2) Adductors of the lower jaw and retractors of the upper jaw (3) Protractor of the jaw and (4) Depressor of the lower jaw.

3. The muscles show a good deal of variations in the arrangement of muscle fibres and tendons.

4. Generally those muscles which are meant for quick action show simple parallel type of fibre arrangement and the most complex pattern forming multipinnate pattern is found where a stronghold rather than a quick action is an advantage.

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Studies on the effect of Copper, Manganese and Zinc on growth and amino-acid Metabolism in *Raphanus sativus* L.

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Introduction

Micro-elements are essential for various physiological activities and if available in optimum doses will enhance the growth of the plants. It also plays an important role in influencing a number of enzymes as well as growth and metabolism of plants. Zhezhel and Yardya (1956) have advocated that it is a good cultural practice to apply micro-elements under presowing treatment. Timashov (1958) observed increased amino-acid synthesis in the leaves of potato plants by the application of copper. A flavoprotein enzyme which brings about the reduction of nitrite to hydroxylamine in the synthesis of amino acids and proteins was found in leaves of soyabean by Nason *et al.* (1954) and for its action manganese was found to be essential. Hoagland (1944) reported that zinc is component of catalytic system necessary for amino-acid synthesis. Bertrand *et al.* (1964) found that the synthesis of amino-acids increased by the application of zinc.

Material and Method

Present investigations were carried out on *Raphanus sativus* L. (Var. white long). The micro-elements namely copper, manganese and zinc were used in the form of $CuSO_4$, $MnCl_2$ and $ZnSO_4$ respectively. Preliminary experiments were performed to find out the concentrations at which the maximum germination took place (Das and Srivastava, 1966). It was observed that maximum germination was in aqueous solution of 10 ppm each of $CuSO_4$, $MnCl_2$ and $ZnSO_4$. Healthy seeds of approximately uniform weight and size were taken and washed in distilled water and then soaked for twenty four hours, separately, in solutions of 10 ppm each of $CuSO_4$, $MnCl_2$ and $ZnSO_4$. They were then removed, thoroughly washed in running water and sown in soil in pots. A control was also run in which seeds were soaked in distilled water for twenty four hours and then sown in pots. Dry matter of roots and shoots were recorded in fifteen days old plants. Free amino-acids were also separated by two dimensional paper chromatography technique in roots and shoots of fifteen day old plants and were estimated quantitatively by Klett Photo-electric colorimeter in terms of α alanine (Fowden, 1954). The growth results were subjected to statistical analysis for F test and critical difference at five and one percent level have been reported.

Results and Discussion

A study of the dry matter data reveals that maximum dry matter was found in the root and shoot of Zn treated plants and minimum in control as compared to all other treatments (Table I). Similar observation has also been reported by Haas (1937) by the application of Zinc as a foliar spray.

TABLE I

The effect of Cu, Mn and Zn on dry matter accumulation in Raphanus sativus L. *plant in fifteen days old plants*

(Average of 16 Plants, 4 plants in each pot)

Growth characters	Control	$CuSO_4$	$MnCl_2$	$ZnSO_4$	S. E.	C. D. 5%	C. D. 1%
Shoot dry matter (gm/plant)	0·230	0·380	0·356	0·383	0·027	0·081	0·112
Root dry matter (gm/plant)	0·037	0·059	0·050	0·064	0·014	0·044	0·063
Total dry weight/plant	0·267	0·439	0·406	0·447	0·053	0·250	0·220

Along with increase in dry matter, there has been an increase in free amino-acids in the shoot of Zn treated plants as compared to rest of the treatments including control (Table II). This was due to the favourable effect of zinc on the amino-acid synthesis as also reported by Hoagland (1944) and Nason *et al.* (1950). The amount of γ–amino butyric acid, glutamic acid, aspartic acid, serine and glycine were found to be maximum in Zn treated plants over all the treatments (Table II). Free amino-acids in the roots of zinc treated plants showed maximum total amount as compared to rest of the treatments including control (Table II). The higher total amount of free amino-acids in the shoot and root of Zn treated plants, as compared to rest of the treatments further supported the view that Zinc favoured amino-acid synthesis.

TABLE II

The effect of Cu, Mn and Zn on the amino acids in the root and shoot of fifteen days old plants of Raphanus sativus L.

Microgram/100 mg (dry weight basis)

Name of amino acids	Control		$CuSO_4$		$MnCl_2$		$ZnSO_4$	
	Root	Shoot	Root	Shoot	Root	Shoot	Root	Shoot
Leucine and phenyle alanine	–	66	–	91	–	75	–	100
Valine	–	–	–	–	–	–	–	–
γ Amino butyric acid	45	58	50	66	58	75	66	91
Proline	–	–	–	–	–	–	–	–
β – alanine	–	–	–	–	–	–	–	–
α – alanine	58	91	66	75	75	100	91	122
Glutamic acid	52	100	58	122	59	100	76	155
Threonine	–	–	–	–	–	–	–	–
Agrinine	–	–	–	–	–	–	–	–
Aspartic acid	75	75	100	100	122	75	200	66
Serine and glycine	100	155	200	266	155	250	216	333
Asparagine	–	–	–	–	–	–	–	–
Glutamine	–	–	–	–	–	–	–	–
Cysteic acid	–	–	–	–	–	–	–	–
Unidentified	58	15	100	100	75	75	91	91
Total	388	560	574	820	544	750	740	958

An increase in shoot and root dry matter accumulation has been noted in Cu treated plants as compared to control and Mn treated plants (Table I). The amount of leucine and phenylalanine, γ–amino butyric acid, glutamic acid, serine and glycine were found to be maximum in the shoot of Cu treated plants as compared to control (Table II). There has also been a corresponding increase in dry matter accumulation which indicates that copper treatment has favourably affected the dry matter accumulation and synthesis of amino-acids as against control (Table II). It is interesting to note that aspartic acid was maximum in the shoot of Cu treated plants while the rest of the amino-acids were maximum in Zn treated plants (Table II). The increased amount of aspartic acid over all treatments including control in the shoot of Cu treated plants may be due to an increased aspartic acid synthesis. Timashov (1958) also observed increased amino-acid synthesis by the application of copper.

A study of free amino-acids of the root showed that higher amount of amino-acids were recorded in Cu treated plants as compared to control (Table II). The higher accumulation of free amino-acids in roots of Cu treated plants over control is due mainly to the increased amount of γ-amino butyric acid, glutamic acid and aspartic acid. It indicates that the synthesis of these amino-acids is dependent on the activity of enzymes which require copper as a co-enzyme Nelson and Dawson (1944). The higher total amount of free amino-acids in copper treated plants as compared to control further supported the view that copper favoured amino-acid synthesis. James *et al.* (1948) reported that the application of copper catalyses the oxidation of amino-acids and secondary amines.

Summary and Conclusion

A study on the effects of Cu, Mn and Zn treatment to the seeds of *Raphanus sativus* L. (Var. white long) grown in pots in sandy loam soil was conducted. Seeds were treated with 10 ppm. of each of $CuSO_4$, $MnCl_2$ and $ZnSO_4$ solutions at the time of sowing. A control was also run in which seeds were treated with distilled water and sown in pots. Dry matter of roots and shoots were recorded in fifteen days old plants. Free amino-acids were also separated in roots and shoots. The results showed that zinc treatment led to an increased growth as indicated by dry matter accumulation in shoot. It was also observed that zinc plays an important role in influencing the synthesis of leucine and phnyl alanine, aspartic acid, glutamic acid, α-alanine and γ-amino butyric acid. The amount of aspartic acid was higher in shoot of copper treated plants as compared to rest of the treatments indicating that copper plays an important role in its synthesis. Finally these studies also indicate that the presowing treatment with micro-elements leads to significant effect on growth and amino-acid metabolism of the plants.

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